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ORIGINAL ARTICLE

Perceptions of inclusion in physical activity and physical education from the perspective of Finnish students

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ABSTRACT

This article examines the subjective experience of inclusion in physical activity from the perspective of Finnish students with and without disabilities (n = 10). A qualitative approach based on written interviews served to reconstruct potentials and challenges of physical activities and physical education. The interviews were qualitatively content analysed using a deductive-inductive approach. The results of the study showed that inclusion, in general, is closely connected to friendships and a sense of belonging for the study participants. In addition to social relationships, motor skills also impacted on students' opportunities of participating in school-based physical activities. While the pedagogical practices of teachers may maximize student participation in PE, recess situations have greater potential for exclusion. Furthermore, gender-specific aspects played a more significant role in the current study in comparison to the perception of special needs of the participants with disabilities.

Keywords: Sport health, Disability studies, Interviewing, Qualitative research, Pedagogy.

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INTRODUCTION

The subjective interpretations of (inclusive) physical education (PE) and physical activity (PA) by individuals with disabilities is a relatively new phenomenon and has become of increasing interest over the past few years. Listening to the voices of people with disabilities can help to provide valuable insights into the ways they experience PA and PE (Spencer-Cavaliere & Watkinson, 2010; Bredahl, 2013; Lamata et al., 2024) and offer the opportunity to facilitate best practices for including these individuals inside and outside of school contexts (Holland et al., 2023; Healy et al., 2013). However, there is still a lack of research taking into account the perspectives of children and youth with and without disabilities (Ruin & Meier, 2018) and broadening the focus of sports and physical activities in different contexts that goes beyond school-based PE (Holland & Haegele, 2021; Holland et al., 2023). The current body of research has mainly examined the reflections of students with certain disabilities, such as visual impairments (Haegele et al., 2018; Ruin, Giese & Haegele, 2021), autism spectrum disorders (Blagrave, 2017; Haegele & Maher, 2022) and physical disabilities (Alves et al., 2018; Goodwin & Watkinson, 2000). The results of the interview study by Ruin, Giese and Haegele (2021) revealed, from the perspective of students with visual impairments, that the participants were confronted with individually perceived motor challenges (e.g. balancing) and fears in the context of PE. Previous research from the perspective of students with disabilities could also identify various barriers to successful participation in sports and physical activity (Blagrave, 2017; Bredahl, 2013; Spencer-Cavaliere & Watkinson, 2010).

The study by Spencer & Cavaliere (2010) showed that social interactions between students with and without disabilities are most likely to occur when friendships exist between the respective students. Bredahl (2013) interviewed a total of 20 adults with various disabilities about their personal experiences regarding their participation in sports and physical activity in Norway. The majority of respondents reported that they were frequently excluded from participating in PE classes by teachers and were often relegated to the role of spectator or assigned individual exercises in separate rooms. This was attributed, among other things, to the teachers' reluctance and missing expertise to adapt classroom activities to the needs of all learners. Several respondents pointed out in this context that they expressed their needs to the teacher but did not feel understood. Thus, the students' individual needs and (dis-)abilities were not adequately taken into account in PE (Bredahl, 2013). In line with the results of Bredahl's study, the research overview by Holland & Haegele (2021) showed, that children and adolescents with disabilities are still often excluded from participating in school-based sports and physical activity due to inappropriate modifications and accommodations. In turn, the study conducted by Lamata et al. (2024) highlighted that the majority of students with disabilities felt included by their peers in the PE class, which is in contrast to the findings obtained in the studies conducted by Healy et al. (2013) and Spencer-Cavaliere & Watkinson (2010).

The results of the study conducted by Ruin & Meier (2018) taking into account the perspective of both, students with and without disabilities, indicated that the teacher plays a central role in whether the specific needs of learners are taken into account in lesson planning and instruction. Teachers are essential to the quality of experiences of students with disabilities by creating supportive and safe learning environments (Holland & Haegele, 2021). However, attempts to promote inclusion of students with disabilities should start with a reflexive look at the unique needs of each individual student (Holland et al., 2023). Still, more research needs to be done to continue to reveal the perspectives of children with disabilities toward PE and PA, taking into account different disabilities (Holland & Haegele, 2021) and including other dimensions of diversity, such as gender, sexual orientation, and age. Reframing research that expands upon established means of traditional qualitative methods is necessary to include the perspectives of individuals with multiple and more severe disabilities in PE (Fitzgerald, 2007; Bredahl, 2013; Blagrave, 2017).

Yet, no studies, to the knowledge of the author, have explored the perspectives of students in a Finnish school context towards their experiences of belonging in PE and PA. This seems important, as social context and local policies and regulations likely influence the way in which students experience PE (Holland & Haegele, 2021). This article aims to address this research gap and reconstruct potentials and challenges of being included in PA and school-based PE from the perspective of Finnish students with and without disabilities. Consequently, this article is guided by the following research question: How do the study participants experience inclusion in the context of PA and school-based PE?

Conceptual Framework: Inclusion as a sense of belonging and acceptance

In order to understand and analyse the perspective of the participants in the present study, a subjectively shaped understanding of the concept of inclusion was used as the conceptual framework guiding this study (Stainback & Stainback, 1990; Spencer-Cavaliere & Watkinson, 2010; Lamata et al., 2024). This understanding is to great extend influenced and shaped by the individual abilities and experiences of the participants (Haegele & Maher, 2023). In recent studies, subjective perspectives on participation and inclusion have been explored primarily in relation to a sense of belonging, acceptance and value (Oldörp et al., 2024; Pesonen, 2016; Pesonen et al., 2015; Spencer-Cavaliere & Watkinson, 2010; Frederickson et al., 2007). The sense of belonging to other people can be seen as a natural need of every human being in the course of their lifelong development (Maslow, 1962). Within the framework of the UN Convention on the Rights of Persons with Disabilities (UN, 2006), the concept of a sense of belonging is not only linked to individual appreciation by others, but also depends on structural conditions (e.g. barrier-free access to public buildings). Following Baumeister & Leary's (1995) understanding, Pesonen (2016) defines the sense for belonging as follows:

> *"Sense of belonging has been defined in the literature as the extent to which an individual feels socially connected, included, respected, accepted, and supported by others in different social contexts" (Pesonen, 2016, p.6).*

This definition suggests that a sense of belonging is a subjective experience that arises in interaction with other people. This feeling can be developed and promoted through active participation and social inclusion. From the perspective of children with disabilities, inclusion is therefore often perceived as a subjective need for belonging and social acceptance and central to its understanding are the feelings and experiences of the individuals (Spencer-Cavaliere & Watkinson, 2010; Haegele & Maher, 2023).

MATERIALS AND METHODS

In view of the above-mentioned points, this research project aimed to understand the students' individual interpretations of inclusion in the context of school-based PE and PA. Due to the methodological difficulties, it is appropriate to refer to this research project as a participatory-oriented project that tried to achieve participation at the individually possible level (Keeley et al., 2019). An orientation towards the respective conditions of the participants was pursued in order to examine individual needs, experiences, and interests from a subjective perspective as best as possible.

Research that expands upon more traditional forms of qualitative methodologies such as participatory action research have been considered useful to take into account the unique needs of study participants with disabilities (Blagrave, 2017; Keeley et al., 2019). In order to take into account the special needs of the participants with disabilities in the present study, written (digital) interviews were conducted with ten students enrolled in public schools in Southern Finland, of which five had certain disabilities. The potential of digital

research approaches, such as written E-Mail based interviews, has recently found its way in qualitative social research (Schiek & Ullrich, 2017). One methodological advantage of written interviews lies in the fact that data categorization can be done more efficiently, as the data is already present in written form and does not have to be transcribed such as in common face-to-face interviews (Meho, 2006). The methodological decision in favour of a written interview instead of a personal interview was also made due to the particular communication needs of several study participants (Keeley et al., 2019). In the present study, the study participants with visual impairments were able to work on the interview questions in digital form with the help of computer-based speech output and their Braille keyboards mostly independently. In comparison to other data collection methods (e.g. face-to-face interviews), there was no time pressure when answering the questions, which some participants appreciated as they had more time to reflect on the questions (Bamton & Cowton, 2002). Moreover, the degree of anonymity or protection offered by an E-Mail based interview offers the prospect of extending interview-based research to interviewer or interviewee who might otherwise consider themselves excluded (Bampton & Cowton, 2002; Karchmer, 2001).

Sample

A total of four different schools participated in the study, with a focus on including different types of schools. The schools included two secondary schools (grades 7-9), one primary school (grades 1-6), and a centre for learning and consulting (grades 1-9). The selection of students was realized through purposeful sampling (Creswell, 2003): The selection of participants was based on characteristics that were regarded relevant for the study. The two diversity dimensions (dis-)ability and gender were particularly considered in the selection of the study participants, as they are of special relevance in sport pedagogical research (Ruin & Stibbe, 2018). A total of ten students with and without disabilities from four different schools participated in the study, including four female students and six male students (Table 1). All students with disabilities were receiving support measures of the third support level ("*special support*") according to the Finnish system of educational support (FNBE, 2016). Beforehand, an information letter was sent to the respective schools, and the consent of the participants or their legal guardians was obtained in written form. Data were collected during a research stay at the Department of Teacher Education, University of Helsinki. The research procedures followed the "*Ethical principles of research in the humanities and social and behavioural sciences*" of the Finnish National Board on Research Integrity TENK (http://www.tenk.fi/en). These guidelines include procedures for handling misconduct and fraud in science, which is primarily the responsibility of each individual researcher. An ethical review was not required for this study because the study did not meet the requirements for an ethical review, as specified by the Ethical Review Board in the Humanities and Social and Behavioural Sciences of the University of Helsinki.

Table 1. Study participants (n = 10).

Pseudonym	Gender	Age (years)	Grade	Disability
Jari	Male	15	9	-
Elias	Male	16	9	-
Kari	Male	14	7	-
Tom	Male	15	7	-
Jussi	Male	10	4	Visual Impairment, Down-Syndrome
Henri	Male	10	4	Autisms-Spectrum-Disorder (ASD)
Kirsi	Female	12	6	Visual Impairment
Ilona	Female	12	6	Visual Impairment, cerebral palsy
Jenni	Female	13	6	-
Kaisa	Female	16	9	Visual Impairment

Data collection

After obtaining demographic data on each school (type of school, number of students, organization of PE classes) and each participant (gender, age, grade, type of disability), written interviews (Schiek, 2014) served for data collection. The students (or their caregivers) received the interview questions by e-mail and had two weeks to answer the interview questions as independently as possible. For this purpose, the interview guide, which was designed in English, was translated into Finnish and made available to the study participants in both languages. The students who were not able to complete the interview guide independently received assistance from a reference person (teacher or parent). The interview guide was adapted to individual needs of the study participants, including digital documents that are accessible to blind individuals and using "*easy read*" as a method of adapting the interview questions to make it easier to understand for study participants with cognitive disabilities. The interview guide was also adapted to the needs of participants with low vision, using materials in high contrast.

In most cases, the questions were first answered in Finnish. Afterwards, the answers were translated into English by the reference person in consultation with the researcher to clarify the answers and further explanations. For some of the study participants with disabilities, the reference person played a crucial role in supporting the participant in understanding and answering the interview questions, and thus served as a "*interpreter*" in this study. Drawing on previous work by Spencer-Cavaliere & Watkinson (2010), the questions in the interview guide initially covered general topics related to play, sports, and physical activity (e.g. What are typical activities in physical education lessons? What do you like the most? What would you like to change?). These questions served to attract the participants' interest in the topic. Subsequently, the guiding questions covered experiences of "*being included*" in PE and PA. The questions were structured in two main groups: Two questions related to experiences of "*being included*" in physical activities and two questions related to perceptions of "*being included*" in PE lessons.

Data analysis

The data analysis was based on the model of qualitative content analysis developed by Mayring (2010). The data evaluation was carried out in a deductive-inductive manner. Data from e-mail interviews were generated in electronic format and thus required little editing or formatting before they were processed for analysis (Meho, 2006). Initially, the deductively formed main categories of the interview guide were used to achieve a pre-structuring of the interview data. The two main groups of the interview guide served as the deductively formed main categories (Table 2).

The interviews were analysed separately by first assigning the statements to the main categories. Then, the main categories were differentiated inductively by summarizing thematic similarities in the individual statements of the students within a main category. The subcategories were thus gradually derived from the material inductively, according to Mayring's approach to category formation. From these thematic similarities in the statements, new subcategories were created, for which coding rules were established.

Table 2. Category system.

Main categories	**Sub-Categories**
Perceptions of "*being included*" in (school-based) physical activities	• Friendships and social relationships. • Motor competence as a barrier to successful participation.
Perceptions of "*being included*" in PE	• Purpose and typical activities of PE. • Teachers' inclusive practices.

Trustworthiness

The trustworthiness of this study was achieved in various ways. The researcher had experience in interviewing and working with children with and without disabilities in various fields in the school and PE/PA context for over 10 years. These experiences enhanced the researcher's understanding of the various activity contexts participants referred to in the interviews (Spencer-Cavaliere & Watkinson, 2010). To validate findings in this study, summaries of each interview were composed and sent to each participant (Bredahl, 2013). Moreover, "*communicative validity*" (Kvale & Brinkmann, 2009) was incorporated by summing up the interviews and asking for clarification in the case of queries. Participants' clarifications were added to the summaries before being approved.

RESULTS

The results of the present study will be presented based on the following two main themes and sub-themes which emerged from the data, including (a) Perceptions of "being included" in (school-based) physical activities (b) Perceptions of "*being included*" in PE. These results reflect the participants' experiences, perspectives and values toward PE and PA.

Perceptions of "being included" in (school-based) physical activities

Friendships and social relationships

The importance of friendships with peers was emphasized in the interviews by both, students with and without disabilities. Participants agreed that friendships play a key role in establishing a sense of belonging to a group. Friendships also played an important role in whether the interviewed students experience access to organized play and sports activities during recess. This is exemplified by the statement of one interviewed student:

> *"It makes me feel part of a group when my friends want me to join their team. In recess it is really important to have your group of friends. I like recess the most, because then I can play football with my friends." (Elias)*

The feeling of belonging to a group and being accepted as a person was also reflected in the statements of students without disabilities. For Henri, it was not just about being part of a team, but also about being included in conversations by their peers and being heard, as highlighted in the following quote:

> *"In hockey, I feel included when teammates talk and listen to me." (Henri)*

In general, the students' experiences revealed that the feeling of acceptance and the sense of belonging were particularly due to relationships with other students showing their interest in the student's hobbies and personal feelings (Pesonen, 2016; Vetoniemi & Kärnä, 2019). However, being on a team seemed not enough to feel included, particularly if a child did not get any playing time. A sense of belonging usually only arises when students experience themselves as equal playing partners and are actually involved in a game (Pesonen et al., 2015). The student's experiences indicated that schoolmates might segregate students with disabilities from physical activities in recess situations. Some students with disabilities highlighted the role of educational assistants as a valuable resource in PE classes and during recess. The following quote by Kaisa, a study participant with an visual impairment, illustrated the supportive role of educational assistants:

> *"In breaks I am together with my personal assistant. I go for a walk because I don't want to sit somewhere." (Kaisa)*

While previous research identified educational assistants as an important partner in developing inclusive classrooms (Mihajlovic, 2024), the physical presence and overprotection of educational assistants may also hinder the development of social skills, distancing students with disabilities from their peers (Goodwin et al., 2022).

Motor competence as a barrier to successful participation

A certain level of motor competence in certain sports was considered necessary to be respected by classmates and to be able to participate on an equal footing in a game. Jari explained that making a contribution to his team and having a valued role made him feel included:

> *"Well, I think in sports you have to be good in a certain sport or game. Then you feel part of the community because other players will respect you." (Jari)*

The student's statement illustrated that a sense of belonging only arises if the player is actively involved in the game and is considered legitimate participant based on a certain level of (motor) competence (Spencer-Cavaliere & Watkinson, 2010).

Competitive sports and games also generated interest among the students with disabilities. One student with an intellectual disability (Jussi) described football as his favourite sport, but he was unable to find access in free play situations on the schoolyard or outside of school. On one hand, the student was not confident to join a football team, and on the other hand, he was afraid of being rejected:

> *"I really like to play football, but I am not good in playing it. And if I would join a football team they would never let me play" (Jussi)*

It became evident that along with positive associations with sports and games, unpleasant statements were also present, which were associated with fears and shame. These experiences or fears of failing were mainly expressed among the students with disabilities, which may impact negatively on their sense of belonging (Pesonen, 2016; Personen et al., 2015).

Perceptions of "being included" in PE

Purpose and typical activities of PE

Recent studies concluded with a student view of PE as a break from other subjects and more non-educational than a subject of learning (Lyngstad, Bjerke, & Lagestad, 2019). Students in this study showed a widespread understanding about the purposes of PE, including the promotion of health, fun and wellbeing, as the following quotes illustrated:

> *"PE is good for health and it is fun." (Jenni)*
> *"Sport makes you feel better. Sport is a hobby for me." (Jussi)*

Regardless of having a disability or not, participants mentioned similar aims of the subject of PE. However, most participants interpreted PE as fun activities together with friends and not as a relevant learning perspective. When being asked about typical activities in PE, students reported various sports, games and physical activities. Interestingly, the male participants stressed the importance of competitive ball games such as football, floorball and ice-hockey. Female participants mentioned more individual sports such as swimming and skiing. Moreover, one participant with a visual impairment (Kaisa) highlighted the importance of disability sports such as goalball and showdown.

In the four schools that participated in this study, PE classes were separated by gender starting from the 5th grade, which also seemed to have an impact on the selection of specific sports and physical activities. Berg & Lahelma (2010) attributed the country-specific traditions of separating boys and girls in Finnish to the fact that in these situations, the body is the focus of the educational activities. While some participants highlighted gender differences between boys and girls regarding the PE classes, the teachers also seem not to involve the students in the selection of activities, indicating a rather teacher-centred learning approach:

> *"The activities depend a lot on what the teacher wants. For boys it is more sports like football or other ball sports, but also fitness sports. Girls do different sports like dancing." (Kari)*

It seemed as if gender-specific "*traditions*" of selecting certain physical activities determined by attributed gender-related roles were not questioned by the PE teacher. A gender difference in Finnish PE has also been identified in previous research: Lyyra (2013), for instance, revealed that girls prioritise health-related PE and social and emotional skills, while boys prioritise more competitive physical activities and challenge. Overall, from the perspective of the study participants, gender-specific aspects were more in the focus of PE than possible challenges of including students with disabilities.

Teachers' inclusive practices

In PE classes, the pedagogical practices of the teachers played a central role. Most teachers attempted to motivate all learners, including students with disabilities, to participate in class through appropriate modifications and accommodations. Overall, most teachers in this study seemed to create a positive atmosphere and tried to foster feelings of belonging by showing interest in the individual needs and interests of their students. For instance, Ilona reported that:

> *"Our teacher always tries to help us to participate in class. For example, she talks with us about the rules of the games and really cares about our own opinion." (Ilona)*

During the lessons, physical activities were often adapted to the individual needs by the teacher, which provided greater opportunities for participation. However, a sense of belonging was mainly promoted when the students experienced themselves as a legitimate partner in PE and were prevented from feeling different (Lamata et al., 2024). This was evident in several interviews with the students (Kari, Tom, Jenni, Kaisa, Ilona). In certain situations, the teacher tried to enable the individual students to have the most positive experiences possible. However, this pedagogical approach reached its limits, for example, when the teams are formed independently by the students and certain students are chosen last. In this context, the feeling of mutual recognition played an important role. According to one student, this feeling of being valued as an equal partner by their peers only occurred when the teacher does not interfere in the process of team formation:

> *"Our teacher always tries to arrange equal teams but this doesn't mean that it feels equal. It sometimes feels as if you play in this team because the teacher wants you to play there." (Kirsi)*

The comments made by the student with a visual impairment in relation to team allocation suggest a strategy characterized by a prosocial approach. Through the pedagogical control of team formation, the teacher apparently aimed to achieve equal teams in which stronger students should help weaker students. However, this did not always meet with approval from the students, as it is calculated that stronger students must often step back and compensate the weaknesses of their partner.

Overall, the interviews did not support the use of certain "*inclusive*" strategies, and instead suggested that PE teachers should try to collaborate and communicate with their students to co-construct inclusive practices that are appropriate in each specific teaching situation (Holland et al., 2023; Haegele et al., 2020). Some respondents also expressed the experience of failing in their attempts to participate in general sports programs offered by sports clubs. The availability of suitable physical activity programs were identified as barriers to participating in extracurricular physical activities and leisure activities.

DISCUSSION

The purpose of this study was to explore children with and without disabilities' experiences on inclusion in PA and school-based PE. Most of the positive perspectives in relation to peers described by the study participants were associated with feelings about friendship building, which is in line with previous research in the field (Holland & Haegele, 2021). In the school-based physical activities, it was evident that "*being included*" is closely connected to gaining entry to play and being treated as a legitimate participant. In addition to positive social relationships, motor skills also impact on students' opportunities of participating in physical activities during recess. While the pedagogical practices of teachers have an impact on maximizing student participation in PE, recess situations have greater potential for exclusion. During the PE lesson, the teacher has the main responsibility for including students with disabilities, whereas in free play, opportunities to feel included appear to be child directed and determined (Spencer & Cavaliere, 2010). Gaining entry into free play situations that are less structured, such as recess, may be difficult for children with disabilities because other children can often decide who may participate and who not (Spencer & Cavaliere, 2010; Vetoniemi & Kärnä, 2019). In teaching situations, the participants with disabilities in this study felt marginalized when their teachers tried to compensate their disability without their knowledge. Consequently, PE teachers should try to collaborate and communicate with their students to develop (inclusive) practices that are appropriate in each specific teaching situation (Holland et al., 2023).

Regardless of having a disability or not, participants in the present study mentioned similar purposes of the subject of PE. Most participants reveal a view of PE as being responsible for promoting health, fun and wellbeing, but also as a break from other school subjects (Lyngstad, Bjerke, & Lagestad, 2019). Overall, it is noticeable that the diversity dimension "*disability*" has been mentioned less by children without disabilities than dealing with gender-specific issues in PE. Especially regarding the selection of sports and physical activities, gender-specific differences are evident, which are reflected in the interviews of the study participants. Several male students preferred a "*gender-typical*" selection of competitive-oriented teaching content. Other studies also confirm gender-specific differences in relation to the teaching content of PE in Finland (Yli-Piipari, 2014; Lyyra, 2013): Girls are typically taught more in the areas of aerobics, gymnastics, fitness training, and dance in school sports. Typical boys' sports, on the other hand, are soccer, floorball, skiing, and ice games such as ice hockey. This way of dealing with gender differences seems to construct gender as dichotomic and hierarchical, placing higher significance on boys' ability (Berg & Lahelma, 2010). The gender segregation in Finnish schools may stem from educational policies, the position of sport in Finnish culture and the active practice in which male and female teachers construct gender (Berg & Lahelma 2010; Hakala & Kujala 2015). Consequently, I do not argue that co-educational PE would necessarily be a better solution than gender division, but I strongly recommend that teachers would benefit from training of gender awareness (Camacho-Miñano et al., 2021; Metcalfe, 2018).

Limitations

There are obviously limitations to this study. It should be mentioned that due to the language barrier between the researcher and the study participants, certain typical terms or expressions could not be translated directly

in the interviews (some participants mentioned Finnish terms, for example relating to extracurricular sports or different professionals working in the field). Follow-up e-mail correspondence with the participants and the reference person supporting the data collection was utilized to supplement interview data when clarifications or further explanations were needed. The written type of interview was regarded appropriate for the present research to take into account the special needs of some participants. It should also be noted that e-mail interviewing inevitably loses spontaneity in answering the questions, which can be the basis for the richness of data collected in the interviews (Bampton & Cowton, 2002). Moreover, body language and other non-verbal means of communication that are important in face-to-face interviews got lost in the written form of asynchronous interviews (Meho, 2006).

CONCLUSION

Overall, this paper contributes to a growing body of pedagogical research portraying the perspectives of students with and without disabilities in (inclusive) PE and PA. Future research should further take into account the voices of individuals with disabilities to gain a better understanding of what inclusion means to them and to provide important insights for breaking down barriers and thus advancing feelings of inclusion in society (Oldörp et al., 2024). For a long time, adult stakeholders (without disabilities) have been responsible as the "*inclusion experts*", making decisions about disabled young people, often without their input or consent (Maher & Haegele, 2022). Gaining knowledge concerning (disabled) students' experiences of "*being included*" are essential for understanding the barriers and facilitators of inclusive education in school and may have an impact on teaching arrangements, modifications and pedagogical approaches. In the present study, most participants with disabilities were visually impaired, some of them having multiple disabilities. As stated by Holland & Haegele (2021), few studies have explored the perspectives of those with learning disabilities, intellectual disabilities, or hearing impairment. Future research should also take into account these specific disabilities as understanding their perspectives toward inclusion in PE and PA may hold particular value. Moreover, further research should broaden the perspective on PA and also include leisure and recreational sports when designing suitable physical activity programs, as the experiences and interpretations of inclusion from the perspective of individuals with disabilities has been mainly dominated by research within school contexts.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

INFORMED CONSENT STATEMENT

Written informed consent has been obtained from the participants and legal guardians to conduct and publish this study.

DATA AVAILABILITY STATEMENT

The data presented in this study are available on request from the corresponding author.

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REFERENCES

Bampton, R., & Cowton, C. J. (2002). The E-Interview. Forum Qualitative Sozialforschung Forum: Qualitative Social Research, 3(2). https://doi.org/10.17169/fqs-3.2.848

Baumeister, R.F., & Leary, M.R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. Psychological Bulletin, 117(3), 497-529. https://doi.org/10.1037/0033-2909.117.3.497

Berg, P., & Lahelma, E. (2009). Gendering processes in the field of physical education. Gender and Education, 22(1), 31-46. https://doi.org/10.1080/09540250902748184

Blagrave, J. (2017). Experiences of children with autism spectrum disorders in adapted physical education. European Journal of Adapted Physical Activity, 10(1), 17-27. https://doi.org/10.5507/euj.2017.003

Bredahl A. M. (2013). Sitting and watching the others being active: the experienced difficulties in PE when having a disability. Adapted physical activity quarterly : APAQ, 30(1), 40-58. https://doi.org/10.1123/apaq.30.1.40

Camacho-Miñano, M. J., Gray, S., Sandford, R., & MacIsaac, S. (2021). Young women, health and physical activity: Tensions between the gendered fields of physical education and Instagram. Sport, Education and Society, 28(3), 575-593. https://doi.org/10.1080/13573322.2021.1932455

Creswell, J. W. (2003). Research Design: Qualitative, Quantitative and Mixed Methods. London: Sage.

Finnish National Board of Education [FNBE] (2016). National Core Curriculum for Basic Education 2014. National core curriculum for basic education intended for pupils in compulsory education. Helsinki: Finnish National Board of Education.

Fitzgerald, H. (2007). Dramatizing physical education: using drama in research. British Journal of Learning Disabilities, 35(4), 253-260. https://doi.org/10.1111/j.1468-3156.2007.00471.x

Frederickson, N., Simmonds, E., Evans, L., & Soulsby, C. (2007). Assessing the social and affective outcomes of inclusion. British Journal of Special Education, 34(2), 105-115. https://doi.org/10.1111/j.1467-8578.2007.00463.x

Goodwin, D.L., & Watkinson, E.J. (2000). Inclusive physical education from the perspective of students with a physical disability. Adapted Physical Activity Quarterly, 17(2), 144-160. https://doi.org/10.1123/apaq.17.2.144

Goodwin, D.L., Rossow-Kimball, B., & Connolly, M. (2022). Students' experiences of paraeducator support in inclusive physical education: Helping or hindering? Sport, Education and Society, 27(2), 182-195. https://doi.org/10.1080/13573322.2021.1931835

Haegele, J., Kirk, T., Holland, S., & Zhu, X. (2020). 'The rest of the time I would just stand there and look stupid': Access in integrated physical education among adults with visual impairments. Sport, Education, & Society.

Haegele, J. A., & Maher, A. J. (2022). Male autistic youth experiences of belonging in integrated physical education. Autism: the international journal of research and practice, 26(1), 51-61. https://doi.org/10.1177/13623613211018637

Hakala, L., & T. Kujala. (2015). The ethos of sport as a silent partner in PE curricula. World Studies in Education, 16(2), 69-80. https://doi.org/10.7459/wse/16.2.07

Healy, S., Msetfi, R., & Gallagher, S. (2013). 'Happy and a bit nervous': The experiences of children with autism in physical education. British Journal of Learning Disabilities, 41(3), 222-228. https://doi.org/10.1111/bld.12053

Holland, K, & Haegele, J A. (2021). Perspectives of students with disabilities toward physical education: A review update. Kinesiology Review, 10(1), 78-87. https://doi.org/10.1123/kr.2020-0002

Holland, K., Haegele, J. A., Zhu, X., & Bobzien, J. (2023). "Everybody Wants to be Included": Experiences with 'Inclusive' Strategies in Physical Education. Journal of developmental and physical disabilities, 35(2), 273-293. https://doi.org/10.1007/s10882-022-09852-x

Karchmer, R. A. (2001). The journey ahead: Thirteen teachers report how the Internet influences literacy and literacy instruction in their K-12 classrooms. Reading Research Quarterly, 36(4), 442-466. https://doi.org/10.1598/RRQ.36.4.5

Keeley, C., Munde, V., Schowalter, R., Seifert, M., Tillmann, V. & Wiegering, R. (2019). Partizipativ forschen mit Menschen mit komplexem Unterstützungsbedarf. Teilhabe, 58(3), 96 - 102.

Lamata, C., Grassi, M., Coterón, J., Becerra-Muñoz, W., & Pérez-Tejero, J. (2024). The inclusion of students with special educational needs in physical education according to the opinion of its protagonists: a qualitative study in Spain. Sport, Education and Society, 1-15. https://doi.org/10.1080/13573322.2024.2309350

Lyngstad, I., Bjerke, Ø., & Lagestad, P. (2019). Students' views on the purpose of physical education in upper secondary school. Physical education as a break in everyday school life - learning or just fun? Sport, Education and Society, 25(2), 230-241. https://doi.org/10.1080/13573322.2019.1573421

Lyyra, N. (2013). Pedagogical dimensions in physical education inventory: Evaluating reliability and validity by using confirmatory factor analysis. Studies in sport, physical education and health 198. Jyväskylä: University of Jyväskylä.

Maher, A. & Haegele, J. (2022). Disabled children and young people in sport, physical activity and physical education. Sport, Education and Society, 27(2), 129-133 https://doi.org/10.1080/13573322.2021.1967119

Mayring, P. (2010). Qualitative Inhaltsanalyse: Grundlagen und Techniken (11. Auflage). Weinheim: Beltz Verlag. https://doi.org/10.1007/978-3-531-92052-8_42

Maslow, A. (1962). Toward psychology of being. Princeton, NJ: Van Nostrand. https://doi.org/10.1037/10793-000

Meho, L. (2006). E-mail interviewing in qualitative research: A methodological discussion. Journal of the American Society for Information Science and Technology, 57(10), 1284-1295. https://doi.org/10.1002/asi.20416

Metcalfe, S. (2018). Adolescent constructions of gendered identities: the role of sport and (physical) education. Sport, Education and Society, 23(7), 681-693. https://doi.org/10.1080/13573322.2018.1493574

Mihajlovic C. (2024). Perceptions of Collaboration Between General and Special Educators in Physical Education. Adapted physical activity quarterly : APAQ, 41(2), 306-329. https://doi.org/10.1123/apaq.2023-0104

Oldörp, F., Giese, M., & Grenier, M. (2024). The Influence of Blind Tennis on Subjective Inclusion Experiences-An Ableism-Critical Analysis. Adapted Physical Activity Quarterly, 41(3), 420-439. https://doi.org/10.1123/apaq.2023-0140

Pesonen, H. & Kontu, El. & Saarinen, M. & Pirttimaa, R. (2015). Conceptions associated with sense of belonging in different school placements for Finnish pupils with special education needs. European Journal of Special Needs Education, 31(1), 59-75. https://doi.org/10.1080/08856257.2015.1087138

Pesonen, H. (2016). Sense of belonging for students with intensive special education needs. An exploration of students' belonging and teachers' role in implementing support. Research Report 380, Helsinki University Press.

Ruin, S., Giese, M. & Haegele, A. (2021). Fear or freedom? Visually impaired students' ambivalent perspectives on physical education. Fear or freedom? Visually impaired students' ambivalent perspectives on physical education. British Journal of Visual Impairment, 39(1), 20-30. https://doi.org/10.1177/0264619620961813

Ruin, S. & Meier, S. (2018). "Fragt doch mal uns!" - Potenziale und Herausforderungen im inklusiven Sportunterricht aus Schülerperspektive. Leipziger Sportwissenschaftliche Beiträge, 59(1), 67-87.

Ruin, S. & Stibbe, G. (2018). Physical education and physical education research. An overview of German language publications 2016 - 2017. International Journal of Physical Education, 55(3), 2-55. https://doi.org/10.5771/2747-6073-2018-3-2

Schiek, D. (2014). Das schriftliche Interview in der qualitativen Sozialforschung. Zeitschrift für Soziologie, 43(5), 379-395. https://doi.org/10.1515/zfsoz-2014-0505

Schiek, D. & Ullrich, C. (2017). Using asynchronous written online communications for qualitative inquiries: a research note. Qualitative Research, 17(5), 1-9. https://doi.org/10.1177/1468794117690216

Spencer-Cavaliere, N., & Watkinson, E. J. (2010). Inclusion Understood from the Perspectives of Children with Disability. Adapted Physical Activity Quarterly, 27(4), 275-293. https://doi.org/10.1123/apaq.27.4.275

Stainback, W., & Stainback, S. (1990). Support networks for inclusive schooling. Baltimore: P.H. Brookes.

Vetoniemi, J., & Kärnä, E. (2019). Being included - experiences of social participation of pupils with special education needs in mainstream schools. International Journal of Inclusive Education, 25(10), 1190-1204. https://doi.org/10.1080/13603116.2019.1603329

Yli-Piipari, S. (2014). Physical Education Curriculum Reform in Finland. Quest, 66(4), 468-484. https://doi.org/10.1080/00336297.2014.948688

SUSTAINABILITY & SPORTS SCIENCE JOURNAL

ORIGINAL ARTICLE

Impact of three types of resistance, aerobic, and combined exercises on serum levels of cardiac biomarkers in active older adults

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ABSTRACT

This study explored the impact of eight weeks of resistance, aerobic, and combined exercises on serum levels of Growth Differentiation Factor-15 (GDF-15) and N-terminal pro-brain natriuretic peptide (NT-proBNP) in active older men. Thirty-six participants were randomly divided into three groups (resistance, aerobic, and combined exercise), and serum levels were measured using ELISA kits before and after the exercise protocols. The results revealed a significant 6.4% increase in GDF-15 levels following aerobic exercise, while resistance exercise caused an 18.05% decrease. No notable change was observed in the combined exercise group for GDF-15. For NT-proBNP, aerobic and combined exercises led to reductions of 34.1% and 24.8%, respectively, while resistance exercises resulted in a 37.7% increase. These findings indicate that resistance exercises can reduce GDF-15 levels, which contrasts with the general view that aerobic exercises alone benefit cardiac health. Additionally, aerobic and combined exercises were effective in lowering NT-proBNP levels, whereas resistance exercises had the opposite effect.

Keywords: Sport health, Resistance exercise, Aerobic exercise, Combined exercise, GDF-15, NT-proBNP, Elderly.

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INTRODUCTION

There has been a growing emphasis on maintaining a healthy lifestyle, with numerous studies conducted in health, fitness physiology, and exercise physiology. These studies have focused on various aspects, including nutrition, daily physical exercise, metabolism, cardiovascular diseases, and the consequences and adaptations of exercise.

Physical activity is a powerful non-pharmacological solution for heart problems and related diseases, particularly in older adults. For instance, regular exercise can prevent obesity, heart attacks, hypertension, and arteriosclerosis. Sedentary behaviour can exacerbate these conditions. (Fleg, 2012). Studies have also indicated that aerobic exercise can positively change blood pressure, insulin levels, body weight, blood glucose, insulin resistance, cholesterol, and triglyceride levels (Christenson et al., 2010). As a result, exercise therapy has been recommended as an effective intervention for cardiovascular problems and for improving risk factors, particularly in the older population who may face challenges in managing obesity, hypertension, and diabetes through medications. (Lok et al., 2013).

Previous research has demonstrated the significant role that regular physical activity, encompassing both aerobic and strength training, plays in the non-pharmacological prevention and treatment of cardiovascular issues. This includes improving risk factors such as hypertension, fasting glucose, lipid profile, and obesity (Punia et al., 2016). The determinants of health and mobility in the older participants consist of a combination of primary factors, including genetics and secondary characteristics. Based on previous research findings, it can be concluded that due to the decline in the function of various body organs, the older population is more susceptible to diseases than young and middle-aged individuals. Common diseases that pose a threat to the health of older people include hypertension, diabetes, cardiac arrhythmias, heart failure, falls, osteoporosis, atherosclerosis, and various types of cancer (Fadavi-Ghaffari et al., 2019). Cardiac biomarker Growth Differentiation Factor-15 (GDF-15) also provides prognostic information in these groups (Christenson et al., 2010). GDF-15 belongs to the Transforming Growth Factor (TGF) family and functions as a bone morphogenic protein expressed in the heart, pancreas, prostate, liver, and kidney (Ding et al., 2009).

GDF-15 is prominently expressed in cardiomyocytes after ischemia/reperfusion. In human and murine hearts, increased GDF-15 expression has been observed within hours after myocardial infarction and remains elevated for several days in the infarcted myocardium. Although there is disagreement regarding the site of GDF-15 secretion from cardiomyocytes, the infarcted area has been identified as the primary source of GDF-15. GDF-15 plays a crucial cardioprotective role in the adult heart by activating the Smad2, Smad3, and ALK4/5/7 receptors. Under normal conditions, GDF-15 is not expressed in the heart; however, its levels rapidly increase in response to injuries such as excessive pressure, heart failure, recurrent ischemia/reperfusion, and atherosclerosis (Kempf et al., 2016). GDF-15 has been identified as a predictor of cardiovascular diseases such as heart failure, which is influenced by exercise and physical activity (Abete et al., 2013).

Biomarkers for diagnosing heart failure and monitoring disease progression, such as Natriuretic Peptide type B (BNP) and NT-proBNP, are well-established in clinical guidelines worldwide. These circulating hormone peptides are synthesized and released in response to increased stress on the heart wall due to volume overload or excessive pressure, as well as other conditions like myocardial ischemia or inflammation (Viviane et al., 2004). Plasma concentrations of these hormones rise in patients with left ventricular dysfunction, both systolic and diastolic, and are often used in the clinical diagnosis of heart attacks. NT-proBNP levels increase in response to various signals, including excessive myocardial strain (Serrano-Ostáriz et al., 2011). It is

utilized for predicting heart failure in both elderly and non-elderly populations after adjusting for common clinical risk factors and structural and functional cardiac disorders in the elderly and non-elderly populations (Christenson et al., 2010).

Therefore, NT-proBNP and GDF-15 biomarkers are useful indicators of heart damage. Additionally, it has been established that these two markers increase in conditions preceding heart damage, serving as predictive markers for cardiac injury (Jurczyluk et al., 2003). Despite the identification of new biomarkers (NT-proBNP, GDF-15) in the clinical field for predicting cardiac events, the response of these variables to various physical exercises remains unclear. Consequently, given this information and emphasizing the importance of sports exercises as one of the most well-known interventions for treating and preventing age-related disorders.

MATERIALS AND METHODS

Participants

The study population consisted of older men who volunteered and attended an introductory session, during which comprehensive information about the research topic, objectives, and interventions was provided. Initial screening involved evaluations of health status, including the absence of cardiovascular diseases, diabetes, hypertension, non-smoking status, non-alcohol consumption, no medication use, and no regular physical activity in the past year, with participants aged between 55 and 70 . After obtaining informed consent and confirming participants' health status, particularly their suitability for engaging in a regular exercise program (verified by a physician), 36 individuals were purposefully selected and randomly assigned to one of three groups: 1) Resistance training, 2) Aerobic exercise, or 3) Combined exercise. Ethical approval for the study was granted by Islamic Azad University Science and Research Branch, with the ethical code IR.SSRC.REC.1399.070.

Measurement of serum levels of GDF-15 and NT-proBNP

Serum levels of Growth Differentiation Factor 15 (GDF-15) and N-terminal pro b-type Natriuretic Peptide (NT-proBNP) were measured using a sandwich ELISA method. The specific kits (Human Growth Differentiation Factor 15 ELISA Kit) were obtained from Cusabio, China. Blood samples were collected by trained medical personnel from the Tehran Noor Laboratory. Blood was drawn into vacutainer tubes and allowed to clot for 30 minutes at room temperature. Serum was then separated by centrifugation at 3000 rpm for 15 minutes. The serum was stored at -20°C until analysis. The ELISA procedure was conducted following the manufacturer's instructions provided in the kit brochure, including calibration and validation steps to ensure accuracy. The sensitivity and specificity of the ELISA kits used were verified according to the manufacturer's specifications.

Experimental approach

The research employed a semi-experimental design with a pre-test–post-test framework. Pre-test assessments were conducted one week prior to implementing the research protocol, which included measurements of body composition, physical fitness, and biochemical evaluations. Body composition variables measured included height (using a wall-mounted stadiometer), weight (with a calibrated scale), body mass index (BMI), body fat percentage (measured using the Jackson and Pollock method), muscle mass, and waist-to-hip ratio. Exercise intensity was assessed using the Borg Rating of Perceived Exertion (RPE) scale, with exercises designed and implemented based on the scale's intensity and duration. Aerobic capacity was evaluated using the Queen’s step test. Participants underwent an eight-week intervention with three exercise sessions per week. Forty-eight hours after the final session, body composition, physical

fitness, and biochemical measurements were repeated. Following the intervention, participants completed a four-week no-exercise period before post-test data collection.

Resistance training protocol

Following the initial measurements (pre-test), individuals in the resistance training group (RT) performed resistance exercises three times a week for eight weeks. The exercise protocol included a 10-minute warm-up, a main session comprising eight movements (leg press, leg extension, leg curl, calf raise, bench press, rowing, triceps pushdown, and biceps curl) with three sets of 10 repetitions at 70% of 1RM, and a 10-minute cool-down with stretching exercises. The intensity and duration were gradually increased during the first two weeks to minimize muscle soreness and reduce injury risk (Viviane et al., 2004; Rangers et al., 2019).

Aerobic training protocol

For the aerobic exercise group, a protocol of continuous exercises, including brisk walking, gentle jogging, and ultimately running at near maximum heart rate, was designed. The exercise protocol was based on the principles, guidelines, and recommendations of the American College of Sports Medicine (ACSM) for the older population and was informed by previous studies. Each session began with 5 minutes of gentle stretching, followed by a 10-minute warm-up period of slow jogging and another 5-minute warm-up to increase the heart rate to approximately 120 beats per minute. The main exercise session lasted about 30 minutes and included brisk walking, gentle jogging, and high-intensity running—the resistance training lasted eight weeks with three sessions per week. A Polar heart rate monitor (model Pox 1000) was used to maintain the correct heart rate range (Lok et al., 2013).

Table 1. Aerobic exercise protocol.

Week 1	**Week 2**	**Week3**	**Week4**
20 minutes running at 45% HRR	25 minutes running at 45% HRR	30 minutes running at 45% HRR	30 minutes running at 55% HRR
Week 5	**Week 6**	**Week 7**	**Week 8**
30 minutes running at 55% HRR	30 minutes running at 65% HRR	30 minutes running at 65% HRR	30 minutes running at 55% HRR

Combined training protocol

Based on previous research, the exercise protocol consisted of combined endurance and resistance training. Each session included a 10-minute warm-up and 40–50 minutes of the main exercise. The main exercise session comprised 15 minutes of endurance training in the first week, gradually increasing to 20 minutes by the eighth week. After a two-minute rest period, resistance training was performed for 25 minutes in the first week, extending to 30 minutes by the eighth week. Finally, a 10-minute cool-down period was used to complete each session. (Fábio et al., 2011).

Statistical analysis

Descriptive statistics were used to summarize the characteristics of the participants and the collected data. The Kolmogorov-Smirnov (K-S) test was employed to assess data normality, and Levene's test was used to check for homogeneity of variances.

Upon confirming normality and homogeneity, one-way analysis of variance (ANOVA) was conducted. Post-hoc comparisons were performed using Scheffe's test. The analysis was structured in a 3x2 format (three groups and two measurement time points) for each dependent variable. Significant interactions between time and group were further analysed with simple ANOVA and Scheffe's post-hoc test. Paired t-tests were used to assess within-group changes over time.

Statistical analyses were performed using SPSS version 24, with a significance level set at $p \leq .05$.

Table 2. Combined exercise protocol.

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
10 minutes of warm-up	10 minutes of warm-up	10 minutes of warm-up	10 minutes of warm-up	10 minutes of warm-up	10 minutes of warm-up	10 minutes of warm-up	10 minutes of warm-up
15 minutes of treadmill running at 55% of maximum heart rate	16 minutes of treadmill running at 55% of maximum heart rate	16 minutes of treadmill running at 60% of maximum heart rate	17 minutes of treadmill running at 60% of maximum heart rate	18 minutes of treadmill running at 65% of maximum heart rate	18 minutes of treadmill running at 70% of maximum heart rate	19 minutes of treadmill running at 70% of maximum heart rate	20 minutes of treadmill running at 75% of maximum heart rate
Bench press: 40% × 2 × 15	Bench press: 40% × 2 × 16	Bench press: 45% × 2 × 15	Bench press: 50% × 2 × 16	Bench press: 60% × 2 × 15	Bench press: 65% × 3 × 12	Bench press: 70% × 3 × 10	Bench press: 75% × 3 × 10
Quadriceps: 40% × 2 × 15	Quadriceps: 40% × 2 × 16	Quadriceps: 45% × 2 × 15	Quadriceps: 50% × 2 × 16	Quadriceps: 60% × 2 × 15	Quadriceps: 65% × 3 × 12	Quadriceps: 70% × 3 × 10	Quadriceps: 75% × 3 × 10
Hamstrings: 40× 2 × 15	Hamstrings: 40% × 2 × 16	Hamstrings: 45% × 2 × 15	Hamstrings: 50% × 2 × 16	Hamstrings: 60% × 2 × 15	Hamstrings: 65% × 3 × 12	Hamstrings: 70% × 3 × 10	Hamstrings: 75% × 3 × 10
Biceps: 40% × 2 × 15	Biceps: 40% × 2 × 16	Biceps: 45% × 2 × 15	Biceps: 50% × 2 × 16	Biceps: 60% × 2 × 15	Biceps: 65% × 3 × 12	Biceps: 70% × 3 × 10	Biceps: 75% × 3 × 10
Lat pull-down: 40% × 2 × 15	Lat pull-down: 40% × 2 × 16	Lat pull-down: 45% × 2 × 15	Lat pull-down: 50% × 2 × 16	Lat pull-down: 60% × 2 × 15	Lat pull-down: 65% × 3 × 12	Lat pull-down: 70% × 3 × 10	Lat pull-down: 75% × 3 × 10
10 minutes of cool-down	10 minutes of cool-down	10 minutes of cool-down	10 minutes of cool-down	10 minutes of cool-down	10 minutes of cool-down	10 minutes of cool-down	10 minutes of cool-down

RESULTS

Table 1 presents the participants' characteristics. The results of the one-way analysis of variance (ANOVA) for age, height, weight, and body mass index (BMI) did not show any significant differences among the participants in the three groups ($p > .05$). Therefore, the participants in the three groups exhibited homogeneity in these factors, indicating variance inhomogeneity among the groups.

Table 3. Individual characteristics of study participants by exercise group.

Group	Age (years)	Weight (kg)	Height (cm)	BMI
Resistance	6.5 ± 3.3	69.1 ± 8.6	164.8 ± 4.6	25.74 ± 3.2
Aerobic	71.4 ± 4.1	71.8 ± 7.2	166.26 ± 6.3	25.81 ± 2.8
Combined	68.6 ± 2.9	73.4 ± 9.5	171.34 ± 4.9	25.1 ± 2.9

One-way analysis of variance (ANOVA) (F) was used to analyse the data and determine differences in the effects of the three exercise methods. The results of the F-test did not show a significant difference between the data of the three groups in the pre-test ($p > .05$). Therefore, the participants in the three groups were homogeneous.

For the post-test analysis, the data obtained in the three groups were evaluated using the F-test, which revealed a significant difference between the three groups ($p = .001$). Post hoc Scheffe's test was used to determine the source of the difference, and the results indicated a significant difference between all three groups (combination resistance, combination aerobic, and aerobic resistance) ($p = .001$).

A paired t-test was used to analyse the time effects within each group. The results indicated a significant difference in the post-test data compared with the pre-test data in both the aerobic and resistance training

groups. Specifically, a substantial decrease in serum GDF-15 levels was observed after resistance training, whereas a significant increase was observed after aerobic exercise. However, the changes observed after the combined training were not statistically significant. One-way analysis of variance (ANOVA) was used to analyse group effects. The results revealed no significant differences among the three groups during the pre-test stage. However, there was a significant difference among the aerobic, resistance, and combined training groups in the post-test stage. The post-hoc Scheffe test was used to determine the source of differences, indicating significant differences between the combined and aerobic and resistance groups.

Table 4. Follow-up test results of groups.

		Total scores	Freedom degrees	Mean Scores	F Score	Significance level
Pre-test	Between groups	25.167	2	12.583	1.580	.221
	Within groups	262.833	33	7.965		
	Total	288.000	35			
Post-test	Between groups	3421.056	2	1710.528	143.785	.000
	Within groups	392.583	33	11.896		
	Total	3813.639	35			

The percentage of change in each group after the training period also indicated a 16.15% decrease in post-test data compared to pre-test data in the resistance training group and a 16.5% increase in the mean post-test data compared to pre-test data in the aerobic training group. However, the changes in the combined treatment group were not statistically significant.

Table 5. Interactive effect of time and group on GDF_15.

	Pre-test	Post-test	Within group observation (*p*-value)
Aerobic	651.91 ± 2.67	693.16 ± 2.36	.001 ◦
Resistance	652.25 ± 2.66	614.66 ± 2.64	.001 ◦
Combined	653.83 ± 3.09	655.00 ± 3.97	.331
p-value	.786	.001 •	

Note. ◦ - Within-group difference. • - Between-group difference.

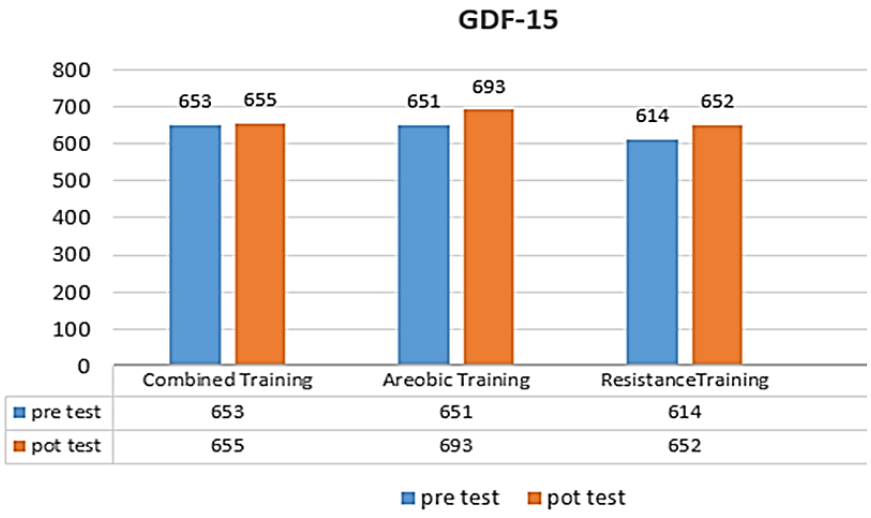

Figure 1. The effect of resistance, aerobic, and combined exercise on GDF_15.

For the statistical analysis of NT-proBNP levels, a paired t-test was used to assess the effect of time within each group. The results indicated significant differences in the post-test data compared to the pre-test data

in all three groups: aerobic, resistance, and combined. Specifically, the aerobic and combined groups experienced a significant decrease, whereas the resistance group showed a significant increase.

Additionally, one-way analysis of variance (ANOVA) was used to analyse the group effect statistically. The results revealed no significant differences among the three groups during the pre-test phase. However considerable; during the post-test phase, a significant difference was observed between the aerobic, resistance, and combined groups. Post hoc tests were conducted to determine the specific location of the differences, which indicated a significant difference between the resistance group and the aerobic and combined groups. However, no significant differences were observed between the effects of aerobic and combined exercises.

The percentage changes in each group after the exercise intervention also indicated an increase in post-test data compared with pre-test data in the resistance training group. Conversely, there was a decrease in the post-test data compared to the pre-test data in the aerobic and combined training groups. Specifically, the resistance training group showed a 37.7% increase after eight weeks of training, while the changes in the aerobic training and combined training groups decreased by 34.1% and 24.8%, respectively.

Table 6. Interaction effect of time and group on NT-proBNP.

	Pre-test	Post-test	Within Group Significance (p)
Aerobic	167.58 ± 2.71	110.33 ± 3.49	.001 ◦
Resistance	167.25 ± 1.91	230.16 ± 3.73	.001◦
Combined	169.50 ± 3.52	127.16 ± 2.28	.001 ◦
Inter-group	.924 •	.001 •	-

Note. ◦ - Within-group difference. • - Between-group difference.

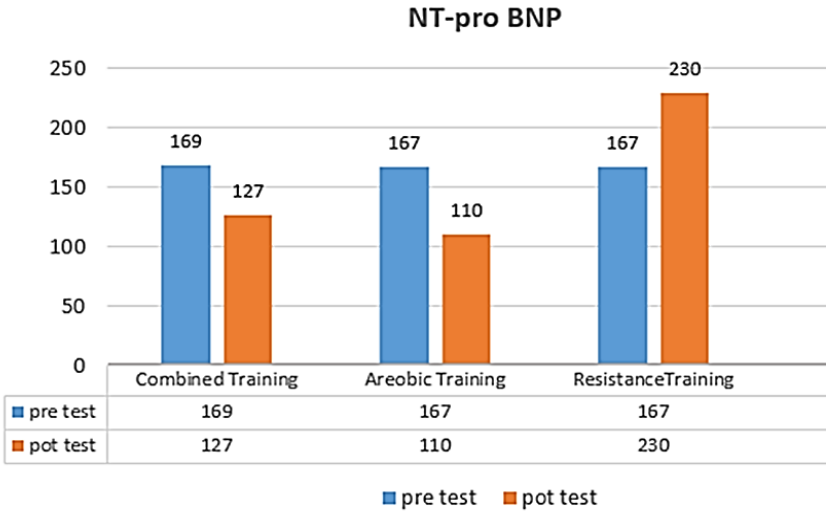

Figure 2. The Effect of resistance, aerobic, and combined exercise on NT-proBNP.

DISCUSSION

The primary objective of this study was to evaluate the distinct effects of resistance, aerobic, and combined exercises on the serum levels of growth differentiation factor 15 (GDF-15) and N-terminal pro-brain natriuretic peptide (NT-proBNP) in active older men.

Consistent with Galliera et al.'s (2014) findings, this study also reported a significant increase in the levels of GDF-15 following aerobic exercises, including both a period of aerobic training and a single session of maximal rugby activity. Similarly, the study by Rangers et al. (2019) also reported a significant decrease in the levels of GDF-15 after an eight-week resistance training program.

It is important to note that Hoffman et al. (2015) reported that serum levels of GDF-15 are higher in older adults than in younger individuals and that there is an inverse relationship between GDF-15 levels and muscle mass, as well as a positive correlation with age. Furthermore, the findings of Xie et al. (2019) suggest that increased levels of GDF-15 are associated with a higher risk of cardiovascular disease and mortality. Therefore, it can be inferred that implementing resistance exercises may increase muscle mass, resulting in a significant decrease in GDF-15 levels, given the inverse relationship between muscle mass and GDF-15 levels.

It is important to note that this study focused on the effects of resistance, aerobic, and combined exercises on the serum levels of GDF-15 and NT-proBNP in active older men, and no changes were made to the information, citations, or references.

Given the link between high levels of GDF-15 and increased cardiovascular mortality, elevated levels of this biomarker in serum blood indicate cardiac damage. The results of the current study imply that, despite previous research, resistance exercises have a more significant positive impact on the GDF-15 factor than aerobic exercise, contrary to the common belief in society. In terms of reducing serum levels of GDF-15, aerobic exercise is more effective in improving cardiac risk factors and reducing the likelihood of cardiovascular mortality in older individuals. After aerobic exercises, there was a significant increase of 16.50%, while after resistance exercises, there was a decrease of 16.15%. No significant change was observed after the combined exercises.

Regarding NT-proBNP, the findings of this study align with the research of Bordbar et al. (2013), who reported an increase in this factor after resistance training and a decrease after aerobic exercises, consistent with the rise seen after resistance exercises. Furthermore, this study's results are consistent with the research of Arbab et al. (2016), which demonstrated a significant reduction in NT-proBNP after combined (resistance-endurance) exercises . However, conflicting results can be seen in the research of Rangers et al. (2019), which reported a decrease in NT-proBNP after eight weeks of resistance training, as well as in the studies of Serrano et al. (2011) and Valls et al. (2014), which showed no significant change in NT-proBNP after resistance exercises. In contrast, Favio et al. (2008) demonstrated that in basketball and football athletes, NT-proBNP significantly increases indicating a significant decrease of 34.1% and 24.8% after aerobic and combined exercises, respectively, and a substantial increase of 37.7% after resistance exercises.

Study limitation

The present study had several limitations. Firstly, it was conducted over a defined temporal scope, specifically from the second half of 2019 to the first half of 2020, and involved participants from Zanjan Province. The study focused on examining the effects of aerobic, resistance, and combined exercise on biochemical and metabolic markers of heart health. Uncontrollable limitations include participant attrition, where some individuals dropped out of the exercise program or had issues with blood sample collection. Additionally, despite providing dietary guidelines and lifestyle recommendations, there was insufficient control over participants' nutrition and sleep. The potential use of medications by participants, which was not reported or controlled, also represents a limitation. Furthermore, variability in participants' emotional and psychological states during the exercise protocol and blood sample collection was not controlled. Lastly, there was the

potential for unavoidable measurement errors by the researcher, exercise implementers, and laboratory personnel.

CONCLUSION

The current study's results suggest that although previous research has found aerobic exercises positively impact cardiac factors, resistance training is more effective in improving risk factors, mainly by reducing serum GDF-15 levels. Furthermore, aerobic and combined exercises were shown to decrease NT-proBNP levels, while resistance exercises led to an increase in this factor. These findings imply that the common perception in the community regarding the benefits of aerobic exercises on cardiac health may be partially accurate.

AUTHOR CONTRIBUTIONS

H. N., A. S., H. R., and H. H., contributed equally to the study. H.N., conceptualized the study, designed the research methodology, and supervised the overall project. Conducted data analysis and interpretation of results. Drafted and revised the manuscript for intellectual content. A.S., contributed to the development of the research design and methodology. Assisted in data collection and performed statistical analysis. Reviewed and edited the manuscript for clarity and accuracy. H.R., participated in the recruitment of participants and facilitated data collection. Provided critical insights into the interpretation of findings and contributed to manuscript revisions. H. H., assisted in the literature review and theoretical framework of the study. Contributed to the drafting of sections of the manuscript and ensured compliance with ethical standards in research. All authors have read and approved the final manuscript and agree with the authorship order.

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REFERENCES

Abete, P., Testa, G., Della-Morte, D., Gargiulo, G., Galizia, G., De Santis, D., & Cacciatore, F. (2013). Treatment for chronic heart failure in older people: Current practice and problems. Heart Failure Reviews, 18(4), 529-551. https://doi.org/10.1007/s10741-012-9363-6

Arbab, G., Nikparvar, M., Gaeini, A. A., & Sobhani, A. (2017). The effect of eight weeks of concurrent exercise on NT-proBNP and ferritin serum levels of beta thalassemia major patients. Bimonthly Journal of Hormozgan University of Medical Sciences, 20(1), 10-17.

Bordbar, S., Moghadasi, M., Babaei Beigi, M., Aslani, A., Rahimi, E. & GharehKhan, M. (2013). Comparison of acute and long-term effects of resistance and endurance training on brain natriuretic peptide levels in middle-aged men. Sports and Biological Sciences, 8(1), 8-42.

Christenson, R. H., Gottdiener, J. S., Kop, W. J., & Seliger, S. L. (2010). Dynamic cardiovascular risk assessment in older adults: The role of repeated N-terminal pro-B-type natriuretic peptide testing. Journal of the American College of Cardiology, 55(5), 441-450. https://doi.org/10.1016/j.jacc.2009.07.069

Ding, Q., Mracek, T., Gonzalez-Muniesa, P., Kos, K., Wilding, J., Trayhurn, P., et al. (2009). Identification of macrophage inhibitory cytokine-1 in adipose tissue and its secretion as an adipokine by human adipocytes. Endocrinology, 150(4), 1688-1696. https://doi.org/10.1210/en.2008-0952

Fábio, S., Lira, G., Pimentel, D., & Ronaldo, V. T. (2011). Exercise training improves sleep pattern and metabolic profile in elderly people in a time-dependent manner. Lipids in Health and Disease, 10, 113-124. https://doi.org/10.1186/1476-511X-10-113

Faviou, E., Zachari, A., Nounopoulos, C., Agrafiotis, E., Vourli, G., & Dionyssiou-Asteriou, A. (2008). Elevation of serum N-terminal pro-brain natriuretic peptide after exercise is an index of myocardial damage or a cytoprotective reflection? Journal of Sports Medicine and Physical Fitness, 48(1), 90.

Fadavi-Ghaffari, M., Azad, A., Meimandi, M., Arani-Kashani, Z., & Gorbanpoor, H. (2019). The psychometric properties of the Falls Efficacy Scale in elderly Iranian residents of nursing homes. Iranian Rehabilitation Journal, 17(3), 197-206. https://doi.org/10.32598/irj.17.3.197

Galliera, E., Lombardi, G., Marazzi, M. G., Grasso, D., Vianello, E., Pozzoni, R., et al. (2014). Acute exercise in elite rugby players increases the circulating level of the cardiovascular biomarker GDF-15. Scandinavian Journal of Clinical and Laboratory Investigation, 74(6), 492-499. https://doi.org/10.3109/00365513.2014.905697

Hofmann, M., Halper, B., Oesen, S., Franzke, B., Stuparits, P., Tschan, H., et al. (2015). Serum concentrations of insulin-like growth factor-1, members of the TGF-beta superfamily and follistatin do not reflect different stages of dynapenia and sarcopenia in elderly women. Experimental Gerontology, 64, 35-45. https://doi.org/10.1016/j.exger.2015.02.008

Jerome L. Fleg. Aerobic Exercise in the Elderly: A Key to Successful Aging. Specialty: Aging, Cardiology. Institution: Division of Cardiovascular Sciences. National Heart. Lung and Blood Institute, National Institutes of Health. Address, 2012; 6701- 20892.

Jurczyluk, J., Brown, D., & Stanley, K. K. (2003). Polarised secretion of cytokines in primary human microvascular endothelial cells is not dependent on N-linked glycosylation. Cell Biology International, 27(12), 997-1003. https://doi.org/10.1016/j.cellbi.2003.09.002

Kempf, T., Eden, M., Strelau, J., Naguib, M., Willenbockel, C., Tongers, J., et al. (2016). The transforming growth factor-β superfamily member growth-differentiation factor-15 protects the heart from ischemia/reperfusion injury. Circulation Research, 98(3), 351-360. https://doi.org/10.1161/01.RES.0000202805.73038.48

Lok, D. J., Klip, I. T., Lok, S. I., Badings, E., van Wijngaarden, J., Voors, A. A., & et al. (2013). Incremental predictive power of novel biomarkers (growth-differentiation factor-15, high-sensitivity C-reactive protein, galectin-3, and high-sensitivity troponin-T) in patients with advanced chronic heart failure. The American Journal of Cardiology, 112(6), 831-837. https://doi.org/10.1016/j.amjcard.2013.05.013

Punia, S., Sivachidambaram, K., & Varun, S. (2016). Effect of aerobic exercise training on blood pressure in Indians: A systematic review. International Journal of Chronic Diseases, 2016, 1370148. https://doi.org/10.1155/2016/1370148

Rangers, E., Mirzaei, B., & Rahmaninia, F. (2019). The effect of resistance training on serum levels of high sensitivity troponin I and GDF-15 in elderly men. Journal of Health Promotion Management, 6. https://doi.org/10.22049/JAHSSP.2022.27711.1449

Serrano-Ostáriz, E., Terreros-Blanco, J., Legaz-Arrese, A., George, K., Shave, R., Bocos-Terraz, P., et al. (2011). The impact of exercise duration and intensity on the release of cardiac biomarkers. Scandinavian Journal of Medicine & Science in Sports, 21(2), 244-249. https://doi.org/10.1111/j.1600-0838.2009.01042.x

Viviane, M., Paul, B., Johan, V., Manuella, M., Viviane, V. H., Cathe'rine, D. M., Nadine, P., Floris, L., & Christiaan, J. (2004). Combined endurance/resistance training reduces NT-proBNP levels in patients

with chronic heart failure. European Heart Journal, 25, 1797-1805. https://doi.org/10.1016/j.ehj.2004.07.022

Xie, S., Lu, L., & Li, L. (2019). Growth differentiation factor-15 and the risk of cardiovascular diseases and all-cause mortality: A meta-analysis of prospective studies. Clinical Cardiology, 42(5), 513-523. https://doi.org/10.1002/clc.23159

Valls, M. R. B., Dimauro, I., Brunelli, A., Tranchita, E., Ciminelli, E., Caserotti, P., et al. (2014). Explosive type of moderate-resistance training induces functional, cardiovascular, and molecular adaptations in the elderly. Age, 36(2), 759-772. https://doi.org/10.1007/s11357-013-9584-1

SUSTAINABILITY & SPORTS SCIENCE JOURNAL

ORIGINAL ARTICLE

Sedentarism and use of electronic devices in primary school students: A descriptive study

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ABSTRACT

Sedentary lifestyles, characterized by low physical activity and prolonged screen time, have been associated with negative health effects such as obesity, sleep problems and poor academic performance. The aim of this study was to analyse and describe the levels of sedentary lifestyle and the impact of video game use on the behaviour and health of elementary school students. The sample consisted of 28 students aged 6 to 12 years (13 boys and 15 girls). The Youth Leisure Time Sedentary Behaviour Questionnaire (YLSBQ) and a device use questionnaire (CERV) were used, assessing avoidance factors and negative behaviour related to video games. The main results show that girls showed higher averages of sedentary and avoidance behaviour than boys, while the first cycle of education presented the highest levels of sedentary behaviour. Fifteen percent of the boys and 26% of the girls showed severe problems of video game use, with the third cycle presenting the fewest problems (50% with no problems). This suggests the need to promote active lifestyles and a balanced use of devices to improve the well-being of students and reduce adverse effects on health and academic performance.

Keywords: Technology, Innovation, Sedentary lifestyle, Sedentary time, Technological devices, Video games.

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INTRODUCTION

Sedentarism

Sedentary behaviour is described as the condition of remaining at rest or without movement, which implies the absence of significant caloric energy consumption (Belisario, 2016; Romero, 2009). Sedentary behaviours are characterized as involving energy expenditure equal to or less than 1.5 METs. Examples of these activities include sleeping, sitting, lying down, watching television or forms of entertainment that involve being in front of screens (Pate et al., 2008; Prieto-Benavides, 2020). This trend is due to various factors, such as screen use or family lifestyle, which contribute to the reduction of physical activity (PA) in these developmental stages (Carson et al., 2016). This sedentary lifestyle becomes a determining factor in the development of chronic noncommunicable diseases, such as obesity and overweight (Belisario, 2016).

One of the main causes of sedentary lifestyles in young people and adults is the frequent use of electronic devices and video games, which has been considered insufficient daily tasks to promote and maintain a healthy lifestyle (Zurita-Ortega et al., 2018). Sedentary lifestyles are directly related to the time students spend in front of screens, especially in the interaction with video games, which can be used on various devices and integrate audio and video (Marín-Díaz & García-Fernández, 2005; Belisario, 2016). In this sense, hours in front of screens are closely linked to psychosocial factors and quality of life, due to the great addictive potential, are inducers of violent and aggressive behaviours among young people, turn people into socially isolated beings (Motamed-Gorji et al., 2019) and produce negative effects on school performance, due to absenteeism and a possible decrease in study time (Adelantado-Renau et al., 2019).

Use of screen devices

In recent decades, the use of electronic devices has increased considerably, becoming very present in our lives and completely transforming our society. Due to the increasing use of these technologies, several studies have documented the lack of PA in children and young people, who spend more than two hours daily in front of screens (Fan et al., 2022). Thus, during these developmental stages, sedentary behaviours are more common than PA, because the integration of sedentary habits is more difficult to modify (Fearnbach et al., 2020). Therefore, the American Academy of Pediatrics has recommended that children and adolescents should not spend more than 2 hours a day in front of the TV (Prieto-Benavides, 2020).

Authors such as Saunders et al. (2012) examined the potential positive and negative impacts of sedentary activities. In the case of children, it was observed that an excess of time in front of the TV is linked to lower school performance, sleep problems, difficulties in social interactions and increased alcohol and tobacco consumption, (Prieto-Benavides, 2020; Saunders et al., 2014). Additionally, lack of PA is related to early onset of cardiovascular disease and chronic noncommunicable diseases (Lavie et al., 2019).

Consequences of screen use

The use of electronic devices can have repercussions that depend on the age of the users (Tsang et al., 2023). These consequences occur in different ways depending on different developmental processes and vulnerability (Tsang et al., 2023) and depending on the content exposed and the context in which it takes place (Sharara-Chami et al., 2019). Children under the age of three may be more sensitive to the negative effects of screen exposure due to the rapid growth and plasticity of the brain at these ages (McHarg et al., 2020). Depending on the content, educational programs benefit learning in children, as opposed to video game exposure associated with violent behaviours and lower empathy (Shoshani et al., 2021).

In turn, screen use in primary school students has significant implications for children's health and development (Aparicio et al., 2022). At the physical level, spending too much screen time neglecting physical activity can trigger weight gain, resulting in overweight and obesity (Bakour et al., 2022) and sleep problems, affecting sleep time and quality (Twenge et al., 2019). At the cognitive level, the use of electronic devices can influence academic performance (Arora et al., 2018), developing attention problems and a significant emotional impact due to isolation and reduced social interactions (Daryanti & Fitriahadi, 2022). Finally, at the psychological level these behaviours can foster the development of addictive behaviours, which in turn could trigger psychological disorders such as depression, anxiety and low self-esteem (Feng, 2022).

Recommendations to reduce the use of screens

To combat the abusive use of new technologies, some studies provide general rules and recommendations on the proper use of screens. Some of these recommendations could be the promotion of family engagement with media, to develop a critical approach to violence and its repercussions (Mohammed Abd Elmonem et al., 2021), setting limits on screen time (1.5 hours during school days and 2 hours on weekends and vacations) (Wise, 2018), promoting sleep habits, to improve irritability and distractions (Guerrero et al., 2019).

It can be verified that, during childhood, exposure to screens has to be limited and supervised by an adult (Mohammed Abd Elmonem et al., 2021). Therefore, a study conducted by Brown and the Media and Communications Council (2011), states that screen exposure time depends on age and provides time recommendations for the use of devices (Table 1).

Table 1. Temporary recommendations for the use of electronic devices according to age.

Age	Recommendations
From 0 to 2 years old	No screens
From 2 to 5 years old	Half an hour or an hour a day. From the age of two, children understand and learn more easily through screens, so it is essential that the programs are educational.
From 7 to 12 years old	One hour with adult supervision and provided it is not mealtime.
From 12 to 15 years old	One and a half hours with increased vigilance in social networks.
Over 16 years old	Bedrooms should not have screens

RESEARCH DESIGN

Type of study and participants

A total of 28 primary school students aged 6 to 12 years (13 boys and 15 girls) participated in this descriptive cross-sectional study. Data were collected at the Nuestra Señora del Rosario public school in Dehesas Viejas (Granada). To obtain the sample we took into account sociodemographic data such as sex and age, the grade to which they belonged and the average grade of their academic record.

Instruments

To assess sedentary behaviour, the Youth Leisure Time Sedentary Behaviour Questionnaire (YLSBQ; Atencio-Osorio et al., 2021) was used. The YLSBQ consists of 12 items that assess different specific sedentary behaviours, distributed in four factors that capture sedentary behavioural activities. Each item is measured on a time scale that allows recording the number of minutes devoted to each activity. The reliability of this questionnaire is exposed by a Cronbach's alpha coefficient = 0.867.

To measure the use of electronic devices and video games, the first part of a CERV questionnaire was used. This instrument includes 22 items composed of two parts, grouped in the dimensions avoidance (items: 1,2,3,8,10,11,15 and 16) and negative behaviour (items: 4,5,6,7,9,12,13,14 and 17). This questionnaire was administered individually and a four-point Likert-type scale was used. The sex, age, academic year and grade point average of each participant's academic record were recorded by means of a sociodemographic data questionnaire.

Procedure

Data collection was conducted during the 2023/2024 academic year. The centre, as well as the parents or legal guardians of the participating students, were contacted to provide an oral and written explanation of the nature and purpose of the study. To ensure anonymity and confidentiality, the names of the participants were coded. Each student completed questionnaires on the use of electronic devices and video games. During the administration of the questionnaires, the tutor provided clear and concise instructions and emphasized the importance of answering truthfully. Additionally, he was in charge of supervising the data collection process. Once the students had completed the questionnaires individually and anonymously, they were collected discreetly to preserve the confidentiality of the responses. This study complies with current Spanish legal regulations governing clinical research in humans (Royal Decree 561/1993 on clinical trials), as well as with the ethical principles formulated Declaration of Helsinki 2013 and the law on the protection of personal data (Organic Law 15/1999).

Data analysis

Data are presented as mean and standard deviation, as well as percentages. Due to the descriptive nature of the study, hypothesis testing was not performed, since the objective was only to describe the characteristics of the population. Comparisons between groups were made using data plots, without additional adjustments or regression models. A 95% confidence level was maintained in all data descriptions. Analyses were performed using the SPSS statistical package, version 25.0 for Windows, Chicago).

RESULTS

The present study focuses on analysing and describing the relationship between sedentary lifestyle and hours of screen time among primary school students.

Sedentary lifestyle associated with the use of video games

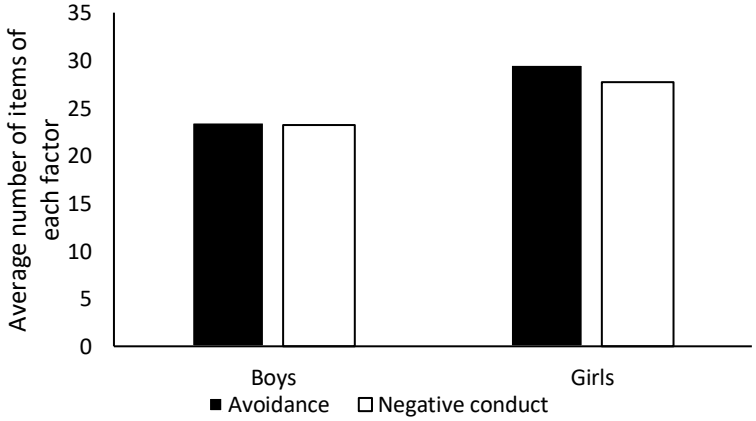

Figure 1. Average sedentary lifestyle associated with problematic video game use (avoidance and negative behaviour) according to sex of schoolchildren.

Figure 1 shows the average sedentary lifestyle associated with problematic video game use, specifically, avoidance factors and negative behaviour in relation to sex. In the case of boys, the average for the avoidance and sedentary behaviour factors is practically identical (23.5 vs. 23.2). However, in the case of girls, the average is higher in both factors, being higher in avoidance than in sedentary behaviour (29.5 vs. 27.7).

Figure 2 shows how in the first cycle the level of avoidance and sedentary behaviour (20.9 vs. 20.2, respectively), associated with problematic video game use, is higher than in the second (16 vs. 14.3) and third cycle (16.1 vs. 14.4). Generally, the avoidance factor tends to have a higher average in all cycles.

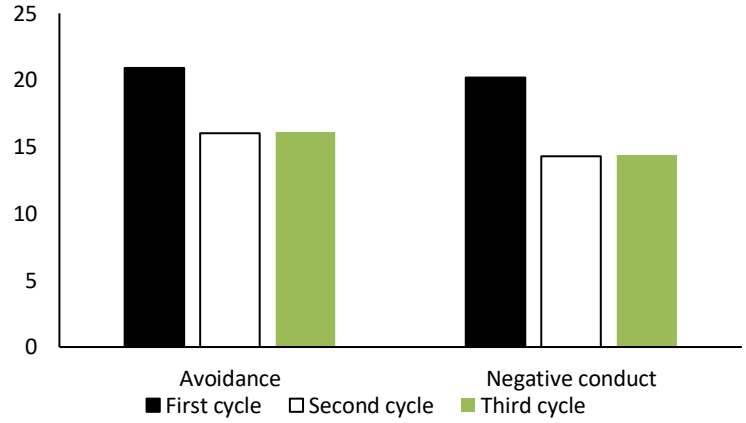

Figure 2. Average sedentary lifestyle associated with problematic video game use (avoidance and negative behaviour) according to schoolchildren's cycle.

Categorization of problematic video game use

The results derived from the categorization of the use of video games reveal that both boys and girls present more potential problems associated with the use of video games (Figure 3). Specifically, 31% of boys and 27% of girls say they have no problems (SP), potential problems increase in both sexes 54% and 47% respectively, and finally severe problems (PS) are shown with 15% in boys and 26% in girls.

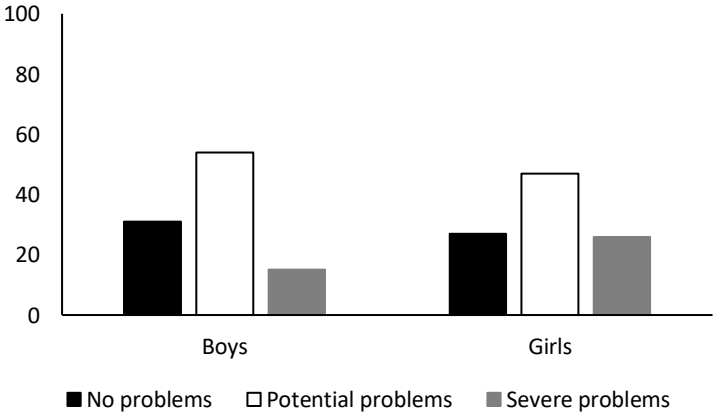

Figure 3. Percentage of problematic video game use by sex.

On the other hand, it is shown that the students with the least problems due to the use of video games are those in the third cycle, where the percentage rises to 50%. On the other hand, students in the second cycle have the highest percentages of severe problems (43%) (Figure 4).

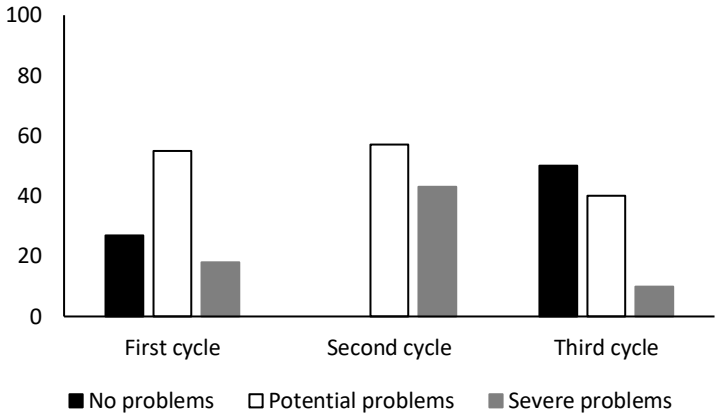

Figure 4. Percentage of problematic video game use as a function of cycle.

DISCUSSION

The present study aimed to analyse and describe the relationships between sedentary behaviour and screen time, specifically through the problematic use of video games in primary school students. The results show that avoidance and sedentary behaviours associated with the use of video games present higher averages in girls compared to boys. In addition, it is observed that the first cycle of primary education presents higher rates of sedentary and avoidance behaviours compared to the more advanced cycles.

Sedentary behaviour and screen time by sex

In this study, girls show a higher average for both avoidance and sedentary behaviour associated with video game use. In contrast, previous research indicates that boys tend to have a higher motivation and frequency of video game use, which increases the likelihood that they will experience negative effects, especially in the development of problem behaviours associated with screen time (Kristen-Lucas & John-Sherry, 2004). However, other studies have highlighted that the influence of gender may vary according to the social and family context Galfo et al. (2022).

Sedentary behaviour as a function of the educational cycle

According to the age of the students, younger schoolchildren seem to be more influenced by problems derived from the use of video games, both in the avoidance factor and sedentary behaviour. This result coincides with the research of Anderson and Dill (2000), who indicate that younger students may be more susceptible to the negative effects of screen time due to their cognitive development and limited ability to manage video game use in a balanced way. This finding is also supported by the study of Throuvala et al. (2020), which reviews how younger students show a greater tendency to use video games as an avoidance mechanism.

However, there are studies that suggest that as students advance in age and educational cycles, problematic video game use may intensify. Labrador et al. (2023) reported that adolescents are more likely to use online video games, which is associated with a higher incidence of loneliness and social anxiety problems. Likewise, Rooij et al. (2014) documented that adolescents may experience increased isolation and poor academic performance to the extent that video game use becomes a predominant activity of their free time.

Limitations and future research

The present study has several methodological and procedural limitations that should be mentioned. Among them are the limitations of a descriptive cross-sectional design, which does not allow us to establish associations between variables or causal relationships and depends on the veracity of the participants' responses to the measures implemented. It is possible that students may have responded in a way that favours a positive self-image. The sample was selected by convenience, which limits its representativeness of the population. In addition, this study does not include an assessment of contextual factors, such as parental influence and social environment, which may have a significant impact on video game use patterns. Nevertheless, the study has important strengths such as participant confidentiality and instruments with high reliability and proven internal validity.

CONCLUSION

In conclusion, this study reveals significant associations between sedentary lifestyles and problematic video game use in elementary school students, with differences by gender and grade level. Through comprehensive data analysis and critical review, the findings suggest that both avoidance factors and problematic behaviours related to video game use may be more prevalent in younger students and girls, although these patterns may vary by context.

It is critical to recognize the needs of each individual and the variability in the effects of video game use and physical activity. Experimental studies could be considered for future research to deepen the understanding of this relationship and its implications in the educational setting. Nevertheless, based on the available data, we can conclude that promoting an active lifestyle that integrates both digital entertainment and physical activity could be beneficial for students' overall development and academic success.

AUTHOR CONTRIBUTIONS

Conceptualization, M.G.-V. and A.R.-M.; methodology and formal analysis, J.L.S.-M. and A.R.-M.; data curation, T.M.-R. and J.L.S.-M.; writing—original draft preparation, M.G.-V. and T.M.-R.; writing—review and editing, J.L.S.-M., and A.R.-M.; supervision, A.R.-M.; funding acquisition, J.L.S.-M. and A.R.-M. All authors have read and agreed to the published version of the manuscript.

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REFERENCES

Adelantado-Renau, M., Moliner-Urdiales, D., Cavero-Redondo, I., Beltran-Valls, M. R., Martínez-Vizcaíno, V., & Álvarez-Bueno, C. (2019). Association between screen media use and academic performance among children and adolescents: a systematic review and meta-analysis. JAMA pediatrics, 173(11), 1058-1067. https://doi.org/10.1001/jamapediatrics.2019.3176

Anderson C. A. & Dill, K. (2000). Video games and aggressive thoughts, feelings and behavior in the laboratory and in life. Journal of Personality and Social Psichology, 78, pp. 772-790. https://doi.org/10.1037/0022-3514.78.4.772

Aparicio, L. G., Lahoza, E. L., Gracia, A. F., Traid, J. R., Bergasa, J. C., & Abad, A. M. D. (2022). Uso de pantallas en la infancia. Recomendaciones. Revista Sanitaria de Investigación, 3(8), 158.

Arora, T., Albahri, A., Omar, O. M., Sharara, A., & Taheri, S. (2018). The prospective association between electronic device use before bedtime and academic attainment in adolescents. Journal of Adolescent Health, 63(4), 451-458. https://doi.org/10.1016/j.jadohealth.2018.04.007

Atencio-Osorio, M. A., Carrillo-Arango, H. A., Correa-Rodríguez, M., Rivera, D., Castro-Piñero, J., & Ramírez-Vélez, R. (2021). Youth leisure-time sedentary behavior questionnaire (YLSBQ): reliability and validity in Colombian University students. International journal of environmental research and public health, 18(15), 7895. https://doi.org/10.3390/ijerph18157895

Bakour, C., Mansuri, F., Johns-Rejano, C., Crozier, M., Wilson, R., & Sappenfield, W. (2022). Association between screen time and obesity in US adolescents: A cross-sectional analysis using National Survey of Children's Health 2016-2017. Plos one, 17(12), e0278490. https://doi.org/10.1371/journal.pone.0278490

Belisario, M. (2016). Videojuegos y sedentarismo en Educación Primaria. Revista Arjé. Edición Especial 12(23), 132- 140.

Brown, A., y el Consejo de Comunicaciones y Medios. (2011). Uso de los medios de comunicación por parte de niños menores de 2 años. Pediatría, 128(5), 1040-1045. https://doi.org/10.1542/peds.2011-1753

Carson, V., Hunter, S., Kuzik, N., Gray, C. E., Poitras, V. J., Chaput, J. P., Saunders, T., Katzmarzyk, P., Okely, A., gorber, S., Kho, M., Sampson, M., Lee, H. & Tremblay, M. S. (2016). Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. Applied physiology, nutrition, and metabolism, 41(6), S240-S265. https://doi.org/10.1139/apnm-2015-0630

Daryanti, M. S., & Fitriahadi, E. (2022). Intensity of The Use of Gadgets to Attention Deficit Disorder in Children. Jurnal Kebidanan, 11(2), 133-146. https://doi.org/10.26714/jk.11.2.2022.133-146

Fan, H., Yan, J., Yang, Z., Liang, K., & Chen, S. (2022). Cross-sectional associations between screen time and the selected lifestyle behaviors in adolescents. Frontiers in Public Health, 10, 932017. https://doi.org/10.3389/fpubh.2022.932017

Fearnbach, S. N., Martin, C. K., Heymsfield, S. B., Staiano, A. E., Newton, R. L., Garn, A.C., Johannsen, N.M., Hsia, D. S., Carmichael, O.T., Ramakrishnapillai, S., Murray, K. B., Blundell, J. E., & Finlayson, G. (2020). Validation of the Activity Preference Assessment: A tool for quantifying children's implicit preferences for sedentary and physical activities. International Journal of Behavioral Nutrition and Physical Activity, 17, 1-13. https://doi.org/10.1186/s12966-020-01014-6

Feng, S. (2022). The Detrimental Effects of Mobile Game Addiction on Chinese Primary School Students and Possible Interventions. Science Insights Education Frontiers, 13(2), 1911-1922. https://doi.org/10.15354/sief.22.re071

Galfo, M., D'Addezio, L., Censi, L., Roccaldo, R., & Giostra, G. (2014). Screen-based sedentary behaviours in Italian school children: the ZOOM8 study. Epidemiology, Biostatistics, and Public Health, 11(3). https://doi.org/10.2427/9473

Guerrero, M. D., Barnes, J. D., Chaput, J. P., & Tremblay, M. S. (2019). Screen time and problem behaviors in children: exploring the mediating role of sleep duration. International Journal of Behavioral Nutrition and Physical Activity, 16, 1-10. https://doi.org/10.1186/s12966-019-0862-x

Kristen-Lucas & John- Sherry (2004) "Sex differences in video game play: A communication-based explanation," Communication Research, volume 31, number 5, pp. 499-523. https://doi.org/10.1177/0093650204267930

Labrador, M., Sánchez-Iglesias, I., Bernaldo-de-Quirós, M., Estupiñá, F., Fernández-Arias, I., Vallejo-Achón, M., & Labrador, F. (2023). Video Game Playing and Internet Gaming Disorder: A Profile of Young Adolescents. https://doi.org/10.3390/ijerph20247155

Lavie, C. J., Ozemek, C., Carbone, S., Katzmarzyk, P. T., & Blair, S. N. (2019). Sedentary behavior, exercise, and cardiovascular health. Circulation research, 124(5), 799-815. https://doi.org/10.1161/CIRCRESAHA.118.312669

Marín-Díaz, V., & García-Fernández, M. D. (2005). Los videojuegos su capacidad didáctico-formativa. Pixel-Bit. Revista de Medios y Educación, 26, 113-119.

McHarg, G., Ribner, A. D., Devine, R. T., Hughes, C., & NewFAMS Study Team. (2020). Infant screen exposure links to toddlers' inhibition, but not other EF constructs: A propensity score study. Infancy, 25(2), 205-222. https://doi.org/10.1111/infa.12325

Mohammed Abd Elmonem, O., Kasem Alaswad, N., & Osman Ali, S. (2021). Effect of Media Use on Aggressive Behavior and Family Relation among School Age Children. Egyptian Journal of Health Care, 12(2), 2013-2025. https://doi.org/10.21608/ejhc.2021.321170

Motamed-Gorji, N., Qorbani, M., Nikkho, F., Asadi, M., Motlagh, M. E., Safari, O., Arefirad, T., Asayesh, H., Mohammadi, R., Mansourian, M., & Kelishadi, R. (2019). Association of screen time and physical activity with health-related quality of life in Iranian children and adolescents. Health and Quality of Life Outcomes, 17, 1-11. https://doi.org/10.1186/s12955-018-1071-z

Pate, RR, O'neill, JR y Lobelo, F. (2008). La definición cambiante de "sedentario". Revisiones de ciencias del ejercicio y el deporte, 36 (4), 173-178.

Prieto-Benavides, D. H. (2020). Actividad física, comportamientos sedentarios y condición física en escolares latinos. Navarra: Universidad Pública de Navarra.

Romero, T. (2009). Hacia una definición de Sedentarismo. Revista chilena de cardiología, 28(4), 409-413. https://doi.org/10.4067/S0718-85602009000300014

Rooij, A. J., Kuss, D. J., Griffiths, M. D., Shorter, G. W., Schoenmakers, T. M., & van de Mheen, D. (2014). The (co-)occurrence of problematic video gaming, substance use, and psychosocial problems in adolescents. Journal of Behavioral Addictions, 3(3), 157-165. Enlace al estudio: Journal of Behavioral Addictions. https://doi.org/10.1556/JBA.3.2014.013

Saunders, TJ, Chaput, JP y Tremblay, MS (2014). El comportamiento sedentario como factor de riesgo emergente de enfermedades cardiometabólicas en niños y jóvenes. Revista canadiense de diabetes, 38 (1), 53-61.

Saunders, TJ, Larouche, R., Colley, RC y Tremblay, MS (2012). Comportamiento sedentario agudo y marcadores de riesgo cardiometabólico: una revisión sistemática de estudios de intervención. Revista de nutrición y metabolismo, 2012.

Sharara-Chami, R., Lakissian, Z., Al-Rayess, H., & Boustany, R. (2019). A "Snap" of Portable Media Use Among Children Two Years and Younger in a Developing Country. Health and Primary Care. https://doi.org/10.15761/HPC.1000157

Shoshani, A., Braverman, S., & Meirow, G. (2021). Video games and close relations: Attachment and empathy as predictors of children's and adolescents' video game social play and socio-emotional functioning. Computers in Human behavior, 114, 106578. https://doi.org/10.1016/j.chb.2020.106578

Throuvala, M. A., Griffiths, M. D., Rennoldson, M., & Kuss, D. J. (2020). Mind over matter: testing the efficacy of an online randomized controlled trial to reduce distraction from smartphone use. International journal of environmental research and public health, 17(13), 4842. https://doi.org/10.3390/ijerph17134842

Tsang, S. M., Cheing, G. L., Lam, A. K., Siu, A. M., Pang, P. C., Yip, K. C., ... & Jensen, M. P. (2023). Excessive use of electronic devices among children and adolescents is associated with

musculoskeletal symptoms, visual symptoms, psychosocial health, and quality of life: a cross-sectional study. Frontiers in Public Health, 11, 1178769. https://doi.org/10.3389/fpubh.2023.1178769

Twenge, J. M., Hisler, G. C., & Krizan, Z. (2019). Associations between screen time and sleep duration are primarily driven by portable electronic devices: Evidence from a population-based study of US children ages 0-17. Sleep medicine, 56, 211-218. https://doi.org/10.1016/j.sleep.2018.11.009

Wise, J. (2018). Screen time: two hour daily limit would improve children's cognition, study finds. British Medical Journal, 362. https://doi.org/10.1136/bmj.k4070

Zurita-Ortega, F., Chacón-Cuberos, R., Castro-Sánchez, M., Gutiérrez-Vela, F. L., & González-Valero, G. (2018). Effect of an intervention program based on active video games and motor games on health indicators in university students: A pilot study. International journal of environmental research and public health, 15(7), 1329. https://doi.org/10.3390/ijerph15071329

SUSTAINABILITY & SPORTS SCIENCE JOURNAL

ORIGINAL ARTICLE

Assessment of explosive force and agility in U19 soccer players following a high-intensity interval training program utilizing plyometric exercises

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ABSTRACT

Aims: This study aimed to assess the impact of a high-intensity interval training (HIIT) program incorporating plyometric exercises on explosive force and agility performance in U17 soccer players. Methods: Twenty healthy male soccer players from the G.S.M team volunteered for the study and provided informed consent. Participants were randomly assigned to two groups: a Control Group (CG) comprising 10 players who continued regular soccer training (Age: 17.6 ± 0.52 years; Height: 183 ± 0.055 m; Body mass: 73.3 ± 4.9 kg; BMI: 23.20 ± 4.07), and a High-Intensity Interval Training Group (HIIT) with the same number of players (Age: 17.7 ± 0.5 years; Height: 1.80 ± 0.313 m; Body mass: 70.9 ± 6.6 kg; BMI: 22.27 ± 2.94). The CG did not participate in any HIIT program, while the HIIT group undertook a weekly plyometric-focused HIIT session for ten consecutive weeks. All subjects underwent two tests: the Squat Jump Test and the T-agility Test, along with the Kinovea software to measure jump flight time to calculate jump height in the SJ test. Results: The intervention group exhibited significant improvements in both the Squat Jump and T-agility test results, indicating enhanced explosive force following the ten-week HIIT program (Squat Jump: t = -3.163, p = .012; T-agility: t = 4.960, p = .000) compared to the control group. These results suggest that the HIIT program effectively enhanced both explosive power and agility performance, thereby potentially improving performance during matches and reducing injury risk among U17 players. Conclusions: The findings of this study provide valuable insights for coaches looking to enhance vertical jump height and agility through HIIT programs featuring plyometric exercises. The positive effects on explosive force and agility performance may lead to improved match performance and injury prevention among recreational soccer players.

Keywords: Health, Team sports, HIIT, Plyometric exercises, Explosive force, Agility performance.

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INTRODUCTION

Football is a game that includes high speed runs at full or sub-normal speeds, high power projections, quick changes in ball direction. Sports coaches often design a training regime for sports coaching and performance research that covers a range of physiological and mechanical requirements. The training regime is, therefore, ready to use by athletes and coaches for their everyday sports activities. Many team sports (such as football, netball, martial arts and baseball) include intermittent, dynamic and ballistic movement. This requires advanced conditions, along with high aerobic and intermittent sprinting capacity, strong muscles and strength, speed flexibility, speed and adaptability.(Bin Shamshuddin et al., 2020).

Football places substantial demands on the lower body's strength, agility, and explosiveness, which are critical for performance (Ozbar et al., 2014); (Chelly et al., 2010). Although explosive actions constitute a small fraction of match duration, they significantly influence game success (Reilly et al., 2000). High-level soccer performance relies on physical fitness, psychological resilience, and technical skills, especially during small-sided games. To enhance the physical and technical capabilities of young players, innovative training methods are essential (Arslan et al., 2021). Soccer players need focused training regimens to meet the sport's physical challenges (Reilly et al., 2000). While much research addresses the training needs of adult athletes, it is also crucial to develop explosive capabilities in young soccer players. Athletic trainers are vital in creating training systems that cater to the diverse physiological and mechanical demands of athletes, thereby enhancing daily training regimens. When training young athletes, trainers must consider their unique physiological development, as their responses to training can differ markedly from those of adults (Oliveira-Junior et al., 2017). Research indicates that growth spurts are associated with improvements in physical performance (Aouichaoui et al., 2012); (Oliveira-Junior et al., 2017). A promising method for enhancing football fitness is Optimum Power Load (OPL) training, which focuses on loads that optimize muscle strength production. Studies show that OPL squats lead to significant improvements in football-specific activities like running, jumping, and agility, thereby positively affecting well-trained athletes' performance (Ribeiro et al., 2020). By tailoring training programs to the physiological changes experienced by young athletes, trainers can facilitate optimal development and enhance performance outcomes.

Muscle strength is essential for daily activities and performance in competitive sports (Ruiz et al., 2008). Exercise intensity significantly impacts physiological adaptations and athletic performance (Rosenblat et al., 2020). This intensity typically involves short bursts of strength training at levels close to VO2max (above 80% VO2max), interspersed with rest or low-intensity recovery periods, depending on the training method utilized. In team sports, muscle power is crucial, particularly in soccer, where rapid, short-duration movements significantly influence an athlete's fitness and skills. Agility—the ability to maintain balance and quickly change direction without losing control or speed—is a critical component for all athletes, including professional and tactical competitors (Alricsson et al., 2001). Agility encompasses balance, coordination, strength, and speed, offering benefits such as enhanced body stability during quick movements, improved intramuscular control, and a reduced risk of injury or re-injury. The Agility T-Test is one assessment used to evaluate athletes' agility, requiring movements forward, sideways, and backward (Raya et al., 2013).

Interval training (IT) consists of repeated bouts of high-intensity exercise followed by rest or low-intensity activity. The duration of these intervals can vary from seconds to minutes, depending on factors such as exercise mode, intensity, recovery time, number of intervals, and frequency (Buchheit & Laursen, 2013a); (Buchheit & Laursen, 2013b). IT has been utilized for decades for various objectives, including health improvement (Wisløff et al., 2009); (Kemi & Wisløff, 2010); (Weston et al., 2014), performance enhancement, and weight loss. High-Intensity Interval Training (HIIT) and Sprint Interval Training (SIT) are two popular

forms of IT (Naves et al., 2018). HIIT typically targets near-maximum intensity, reaching between 80% to 100% of maximum heart rate (HRmax) or maximum oxygen consumption (VO2max) for intervals lasting no more than 60 seconds (Gillen & Gibala, 2014). Recovery periods, which may include low-intensity exercise or rest, can extend up to 4 minutes (Burgomaster et al., 2005); (Burgomaster et al., 2006); (Jiménez-Maldonado et al., 2018). HIIT is widely used to enhance performance in sports such as football, helping teams prepare for competition. Generally, HIIT sessions are structured within a 30-minute timeframe, incorporating warm-up and cool-down phases (Gibala & Jones, 2013); (Gillen & Gibala, 2014). Despite a growing body of literature, proper regulation of HIIT has not been thoroughly studied (Tschakert et al., 2015), ostensibly due to the numerous manipulable variables, such as intensity, duration of effort and rest, work-to-rest ratios, and recovery types (Martínez-Rodríguez et al., 2021).

Plyometric training (PT) is particularly popular among athletes in dynamic sports, and involves activities such as jumping, hopping, and bounding to enhance dynamic muscular performance (Váczi et al., 2013). In these exercises, muscles undergo a rapid lengthening followed by a shortening (known as the stretch-shortening cycle), utilizing elastic energy stored during the stretching phase (Cavagna, 1977). Plyometric training has been shown to improve muscle coordination and synchronization in sports like football, volleyball, and basketball (MH et al., 2021). Various training protocols, including sprint drills, speed training, and weighted exercises, have been proposed to enhance speed, jumping ability, and agility. Both plyometric training alone and in combination with strengthening exercises yield positive results in sprint performance (Monteiro et al., 2008). High-intensity plyometric training, involving sprints, accelerations, decelerations, and directional changes, is recommended to develop agility in football players. Specific sprint training programs have demonstrated significant improvements in sprint times for distances of 10 and 100 meters (Delecluse et al., 1995).

Given the conflicting and limited data in previous studies, we aimed to evaluate the effectiveness of high-intensity interval training (HIIT) featuring plyometric exercises. Specifically, we sought to assess the impact of a 10-week HIIT program on explosive force and agility in male U17 soccer players. We hypothesized that this training would enhance vertical jump performance and change-of-direction capability.

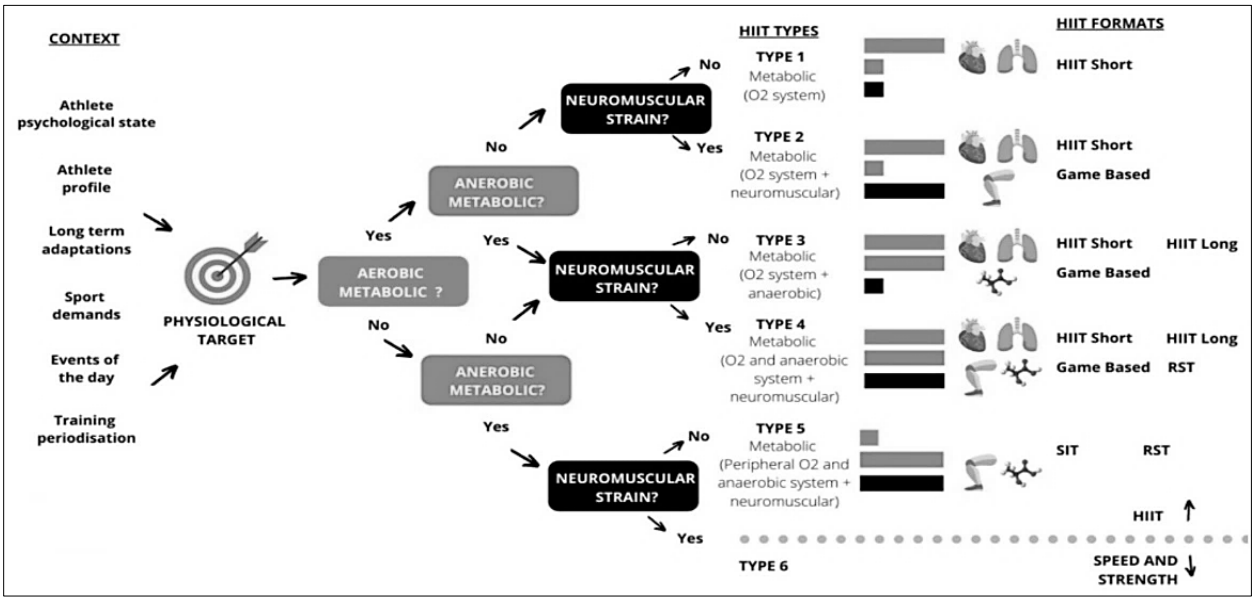

Figure 1. The key figure of HIIT Science. (Laursen & Buchheit, 2019).

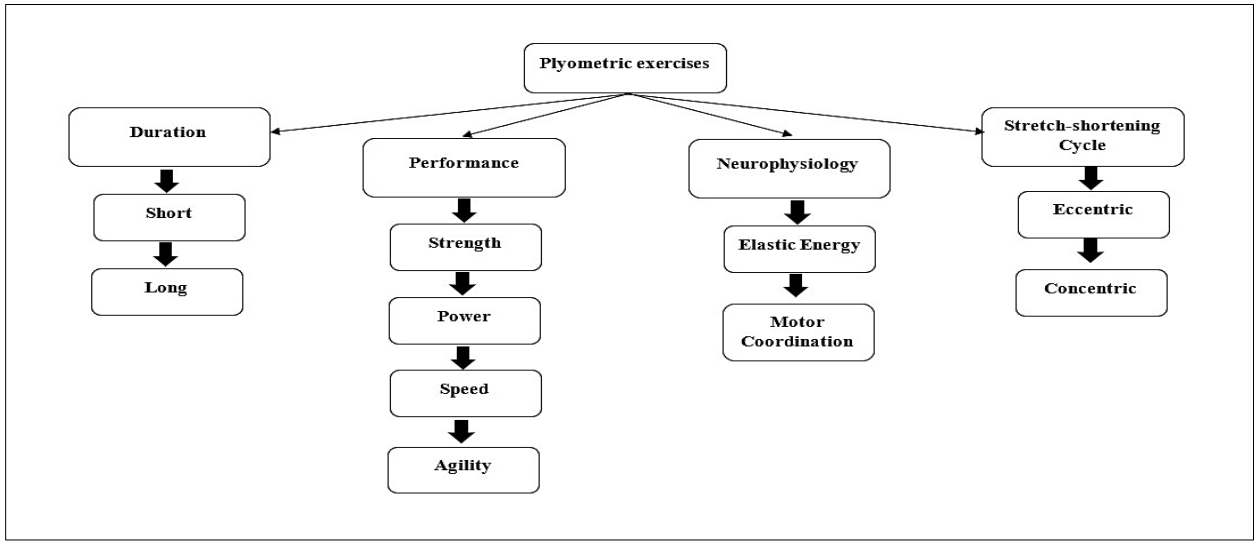

Figure 2. Theoretical framework of plyometric exercises.

MATERIALS AND METHODS

Study area and duration

This study aimed to examine the impact of a 10-week high-intensity interval training (HIIT) program using plyometric exercises on explosive power and agility in U19 football players. Following a quasi-experimental pre-posttest design, the research was conducted over 10 weeks, beginning with the recruitment of participants.

Research design

An experimental randomized pre-test and post-test control group design was employed to test the hypothesis of this study. This design was chosen for its ability to compare the subjects' initial conditions (pre-test) with the outcomes of the post-test after they underwent training. Additionally, this design facilitated the examination of how the independent variable influences the dependent variable. The inclusion of a control group enabled the attribution of differences in post-test results to the treatment itself rather than to extraneous variables.

Participants

The Ethics Committee at the Institute of Science and Technology of Physical and Sports Activities, Mohamed Boudiaf University of M'sila, Algeria, approved the protocol (Date: 15/10/2024). Twenty healthy male soccer players from the G.S.M team were randomly divided into two equal groups (Table 1). A brief medical history was collected from each participant to confirm their eligibility, and none reported any prior surgeries or pain during the testing period.

The study consisted of two groups: a control group (G2) and an experimental group (G1), each comprising 10 participants. The mean ages of the two groups were comparable, with the control group having a mean age of 17.6 years (SD = 0.52) and the treatment group having a mean age of 17.7 years (SD = 0.5), indicating no significant difference. The control group had a mean height of 1.83 cm (SD = 0.055), while the treatment group had a slightly lower mean height of 1.80 cm (SD = 0.3). In terms of body weight, the control group had a mean weight of 73.5 kg (SD = 4.9), which was slightly higher than the treatment group's mean weight of

70.9 kg (SD = 6.6). However, the body mass index (BMI) values of the two groups were similar, with mean BMI values of 23.20 (SD = 4.07) and 22.27 (SD = 2.94) for the control and treatment groups, respectively. This similarity in BMI suggests that the weight difference between the two groups may not be accompanied by a significant difference in body composition when height is taken into account.

Overall, these features suggest that the control and experimental groups are comparable in age and physical attributes, supporting the conclusion that there is no significant difference between them as indicated by the study's results.

Table 1. Participants Characteristics (Mean ± SD)

Variables	**Control (G2)**	**PT (G1)**
	10 players	10 players
Age	17.6 ± 0.52	17.70 ± 0.5
Height (cm)	1.83 ± 0.055	1.80 ± 0.3
Weight (Kg)	73.5 ± 4.9	70.9 ± 6.6
BMI	23.20 ± 4.07	22.27 ± 2.94

Procedure

The study was conducted during the winter of the 2024/2025 competitive season, with a 10-week training program that included technical, tactical, and high-intensity interval training program (HIIT) using plyometric exercises. Each testing session began with a 5-minute conventional run, followed by 10 minutes of body-weight strength and flexibility exercises, 2 minutes of dynamic stretching, and a 5-minute sprint-specific warm-up. There was a 5 to 10-minute break between tests, with each test consisting of three trials per participant, recording the best results. Participants tested outdoors on a synthetic turf field, dressed in their usual training attire and soccer boots. Throughout the study, subjects participated in 3 to 5 soccer training sessions per week, each lasting 90 to 105 minutes. The program training took place once a week for 90 minutes, including a 30-minute warm-up, 30 to 40 minutes of HIIT with plyometric exercises, and 20 to 25 minutes of stretching.

Measures

Squat jump

The Squat Jump (SJ) test is primarily used to assess an athlete's explosive lower-body power, which is an indicator of speed-strength ability. It is often combined with the Countermovement Jump (CMJ), leveraging the stretch-shortening cycle, where muscles are pre-stretched before contracting for the jump. There are two common SJ test variations: the Static SJ and the Dynamic SJ. The Static SJ requires the athlete to hold a flexed semi-squat position for a few seconds before initiating the jump. (Endab, 2024)

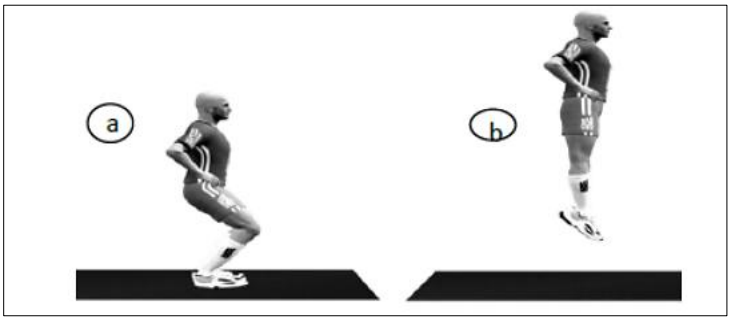

Figure 3. How to perform the Squat jump test.

Participants initiated the Squat Jump with their knees at a 90-degree angle, avoiding any downward movement, and performed a vertical jump with straight legs. They rested for one minute between three trials, with the highest jump recorded for analysis.

Agility T-test

The Agility T-Test was conducted on a 10m x 10m area. Participants began at the central cone and, upon hearing the "*go*" command, sprinted forward to it. They then moved sideways 5m to the right cone, sprinted 10m to the far-left cone, returned to the right cone, and finally backpedalled to the finish line (Bin Shamshuddin et al., 2020). A stopwatch (Skmei) was started when the participant began and stopped when they crossed the finish line. Completion times were recorded in seconds.

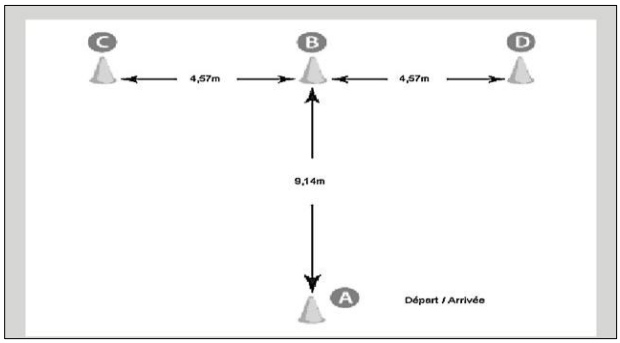

Figure 4. How to perform the T-agility test.

Kinovea two-dimensional motion analysis software

The use of Kinovea version 0.8, an advanced 2D motion analysis tool, greatly improved the post-acquisition phase of the study. This software facilitated a detailed analysis of player movements captured on video. By calibrating the optical jump bar to 90 cm, Kinovea was used to assess jump distance and flight time. This calibration, combined with the software's advanced features, enabled precise calculations of jump height and flight time, allowing for accurate evaluations of the participants' movements.

All jumps were filmed using a Realme 8 phone camera positioned 4 meters from the side of the athlete, as shown in Figure 1. Vertical jump performance was assessed using Kinovea software (Boston, MA, USA). Data were collected at a multi-sports stadium in M'sila Province, Algeria, by researchers from the MLC Laboratory.

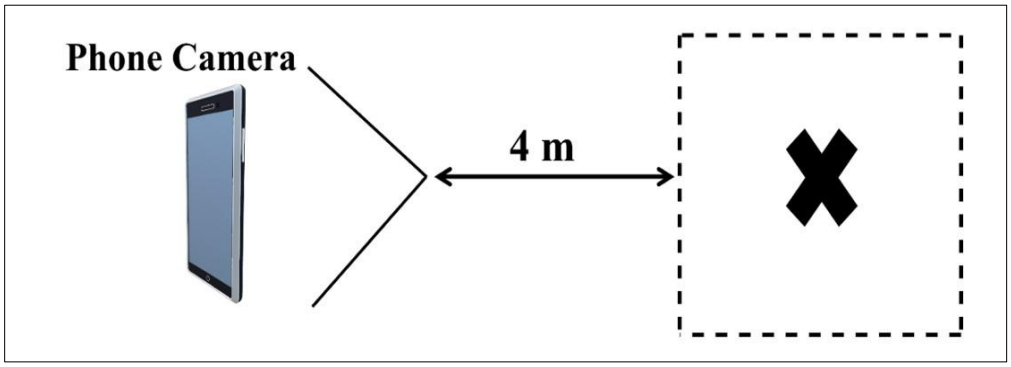

Figure 5. Distance measurements for phone camera setups in video capture.

The high-intensity interval training program with plyometric exercises

Both groups underwent regular soccer training for 10 weeks, which focused on fast footwork, technical skills, positional games (both small and large), as well as offensive and defensive 1 vs. 1 drill, and tactical games with different objectives. The experimental group incorporated high-intensity interval training (HIIT) and plyometric exercises into their routine, replacing a portion of the standard soccer training immediately after the regular sessions (Table 2-3).

Table 2. The high intensity interval training program for experimental group.

Week	Duration	Recovery	Intensity	%Heart Rate
Week 01	2 × 10s	10s	Low	70-75%
Week 02	2 × 15s	10s	Low	75-80%
Week (03+04)	3 × 10s	10s	Medium	80-85%
Week (05+06)	4 × 15s	10s	Medium	85%
Week (07+08)	4 × 20s	10s	High	90%
Week 09	4 × 25s	10s	High	95%
Week 10	4 × 30s	10s	High	100%

Note. *HR: Heart rate. *Duration: Sets x Time.

Table 3. The plyometric exercises for experimental group.

Weeks	Plyometric exercises							
	Squat jump		Side jump		Countermovement jump		Double bound leg jump	
	Rep	Sets	Rep	Sets	Rep	Sets	Rep	Sets
Week 01	06	02	06	02	06	02	06	02
Week 02	06	02	06	02	06	02	06	02
Week 03	08	02	08	02	08	02	08	02
Week 04	08	02	08	02	08	02	08	02
Week 05	06	03	06	03	06	03	06	03
Week 06	06	03	06	03	06	03	06	03
Week 07	08	03	08	03	08	03	08	03
Week 08	08	03	08	03	08	03	08	03
Week 09	06	04	06	04	06	04	06	04
Week 10	06	04	06	04	06	04	06	04

Analysis

Data are expressed as mean ± SD. A two-way repeated-measures analysis of variance (ANOVA) was conducted to evaluate the main effects of time and group (HIITG vs. CG) between baseline and post-intervention assessments. Changes over time in the HIITG were analysed using an ANOVA with repeated measures for all variables, which indicated significant time effects in the 2 × 2 ANOVA. To compare baseline and post-intervention results within each group, paired sample t-tests were performed to assess differences between pre-test and post-test for both the HIITG and CG groups. The significance level was set at $\alpha = .05$. All statistical analyses were performed using PASW Statistics version 25.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Normality of distribution

The normality test results detailed in Table 4 examine the distribution of data for the Squat Jump and T-agility test before and after the intervention in both experimental (EG) and control groups (CG).

For the Squat Jump, the Shapiro-Wilk test indicates a normal distribution in pre-intervention measurements, with the EG scoring 0.884 (p = .146) and CG scoring 0.821 (p = .126). Both p-values exceed the .05 threshold, suggesting that there is no significant deviation from normality. Post-intervention results show improved normality for the EG (0.960, p = .781) and a slightly lower statistic for CG (0.878, p = .125), yet all p-values remain above .05, confirming sustained normality. The T-agility test results mirror these findings, indicating normality in pre-intervention results with the EG at 0.926 (p = .411) and CG at 0.977 (p = .944). Post-intervention, the EG scored 0.948 (p = .641) while the CG scored 0.979 (p = .958), with all p-values again greater than .05, reinforcing the conclusion of normal distribution. Finally, the Shapiro-Wilk test results support the notion that data from both the Squat Jump and T-agility tests conform to normality assumptions in both the pre- and post-test phases for all groups. This finding is vital for justifying the application of parametric statistical methods in evaluating the intervention's effects.

Table 4. Normality test.

Variables	**Test**	**Shapiro-Wilk**			
		Statistic		Significant	
		EG	CG	EG	CG
Squat Jump	Pre	0.884	0.821	0.146	0.126
	Post	0.960	0.878	0.781	0.125
T-agility test	Pre	0.926	0.977	0.411	0.944
	Post	0.948	0.979	0.641	0.958

Validity and reliability

Table 5 presents the reliability and validity outcomes for the squat jump test (SJ) and the T-agility test among under-17 football players. The squat jump test exhibited moderate reliability with a coefficient of 0.608 and a strong Pearson correlation of 0.779 (p < .001), suggesting that it possesses significant reliability and validity. In contrast, the T-agility test demonstrated exceptional reliability, indicated by a coefficient of 0.994 and a nearly perfect Pearson correlation of 0.996 (p < .001), confirming its high reliability and validity. These findings underscore the robust psychometric properties of both tests.

Table 5. Reliability and validity of the SJ and T-agility test among retired physical education teachers.

Variables	**Reliability**		**Validity**
	Pearson correlation	Sig	$\sqrt{reability}$
Squat Jump	0.608	.000	0.779
T-agility test	0.994	.000	0.996

Paired Sample t-Test examination of explosive power and agility performance among both group

Table 6 summarizes the results of a paired-sample t-test comparing pre- and post-performance metrics for vertical and horizontal jumps in both the experimental group (EG) and control group (CG). The experimental group showed significant improvements in several key areas: flight time, jump height, and T-agility test scores. Specifically, flight time increased from a mean of 0.006 seconds (SD = 0.004) before the intervention to 0.014 seconds (SD = 0.006) afterward, with a significant t-statistic of -9.204 (df = 9, p = .004). Jump height also rose notably from a mean of 0.130 meters (SD = 0.107) pre-test to 0.327 meters (SD = 0.097) post-test, resulting in a highly significant t-statistic of -9.978 (df = 9, p < .000). Furthermore, T-agility scores improved, decreasing from 6.549 seconds (SD = 0.099) to 6.013 seconds (SD = 0.085), with a significant t-statistic of 4.960 (df = 9, p = .0003). In contrast, the control group did not demonstrate any significant changes in the measured performance metrics. The standing jump showed minimal variation, with means of 0.322 meters (SD = 0.113) pre-test and 0.310 meters (SD = 0.111) post-test (t = -1.198, df = 9, p = .261). Flight times

remained relatively stable, reported at 0.012 seconds (SD = 0.007) pre-test and 0.010 seconds (SD = 0.005) post-test (t = -9.204, df = 9, *p* = .515). Height measurements similarly indicated no significant change, with means of 0.230 meters (SD = 0.098) pre-test and 0.200 meters (SD = 0.063) post-test (t = -9.978, df = 9, *p* = .132). Lastly, the control group's T-agility test scores slightly worsened from 6.213 seconds (SD = 0.049) to 6.500 seconds (SD = 0.051), but this difference was not statistically significant (t = -5.085, df = 9, *p* = .102).

Table 6. Conduct paired-sample t-test to compare the pre- and post-performance of vertical jump and agility test in the experimental and control groups.

Groups	Variables	Test	Statistic	Paired-sample t-test		
			Mean ± SD	t-value	df	Sig
EG	SJ (m)	Pre	0.318 ± 0.073	-3.163	09	.012
		Post	0.332 ± 0.073		09	
	Flight time (s)	Pre	0.006 ± 0.004	-9.204	09	.004
		Post	0.014 ± 0.006		09	
	Height (m)	Pre	0.130 ± 0.107	-9.978	09	.000
		Post	0.327 ± 0.097		09	
	T-agility test (s)	Pre	6.549 ± 0.099	4.960	09	.000
		Post	6.013 ± 0.085		09	
CG	SJ (m)	Pre	0.322 ± 0.113	-1.198	09	.261
		Post	0.310 ± 0.111		09	
	Flight time (s)	Pre	0.012 ± 0.007	-9.204	09	.515
		Post	0.010 ± 0.005		09	
	Height (m)	Pre	0.230 ± 0.098	-9.978	09	.132
		Post	0.200 ± 0.063		09	
	T-agility test (s)	Pre	6.213 ± 0.049	-5.085	09	.102
		Post	6.500 ± 0.051		09	

Note. Statistical decision: EG: there are statistically significant differences; CG: there are no statistically significant differences.

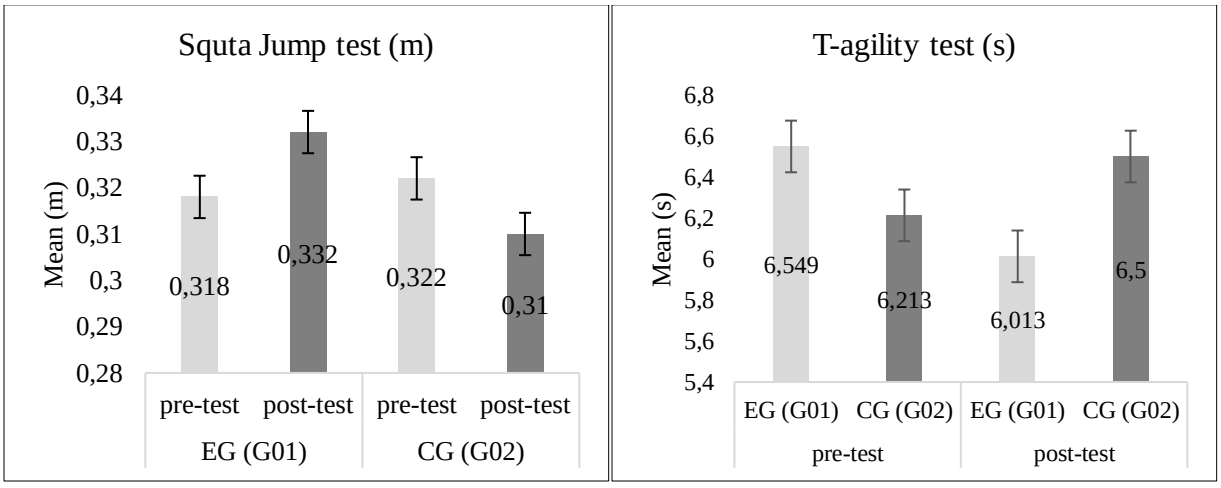

Figure 6. Comparison of pre- and post-test results of squat jump and agility tests for both groups.

In conclusion, the analysis indicates that the experimental group achieved significant enhancements in jump performance and agility following the intervention, while the control group exhibited no meaningful changes. This highlights the effectiveness of the experimental approach implemented in this study.

Two-Way ANOVA test for examining differences in explosive power and agility performance

This study examined the effects of a 10-week training program on vertical jump performance and agility in both experimental and control groups. Table 7 and Figure 7 after analysis of variance (ANOVA) revealed a significant interaction effect between group and time for squat jump performance (p = .003), showing that the experimental group improved their squat jump height from 0.318 ± 0.073 cm to 0.332 ± 0.073 cm, while the control group experienced a negligible change (0.322 ± 0.113 cm to 0.310 ± 0.111 cm). The experimental group also demonstrated a significant increase in flight time (p = .001), indicating enhanced explosiveness, with flight times rising from 0.006 ± 0.004 s to 0.014 ± 0.006 s. Additionally, vertical jump height improved significantly (p = .016) from 0.130 ± 0.107 cm to 0.327 ± 0.097 cm.

In terms of agility, the experimental group improved their T-agility test time from 6.549 ± 0.099 s to 6.013 ± 0.085 s, while the control group's time increased slightly from 6.213 ± 0.049 s to 6.500 ± 0.051 s. The statistical analysis confirmed this improvement with a p-value of .005, indicating that the experimental group performed better on change of direction tasks post-intervention. In summary, the findings indicate that the experimental group achieved significant enhancements in both vertical jump performance and agility measures compared to the control group, highlighting the effectiveness of the 10-week training program.

Table 7. Comparison of Changes in vertical jumps and change of direction performance between experimental and control groups before and after the 10 weeks.

Performance Tests	**Experimental Group**		**Control Group**		**ANOVA Group x Time interaction**
	Pre	Post	Pre	Post	p-value
Squat Jump (m)	0.318 ± 0.073	0.332 ± 0.073	0.322 ± 0.113	0.310 ± 0.111	.003
Flight time (s)	0.006 ± 0.004	0.014 ± 0.006	0.012 ± 0.007	0.010 ± 0.005	.001
Height Distance (m)	0.130 ± 0.107	0.327 ± 0.097	0.230 ± 0.098	0.200 ± 0.063	.016
T-agility test (s)	6.549 ± 0.099	6.013 ± 0.085	6.213 ± 0.049	6.500 ± 0.051	.005

Note. Statistical decision: There are statistically significant differences.

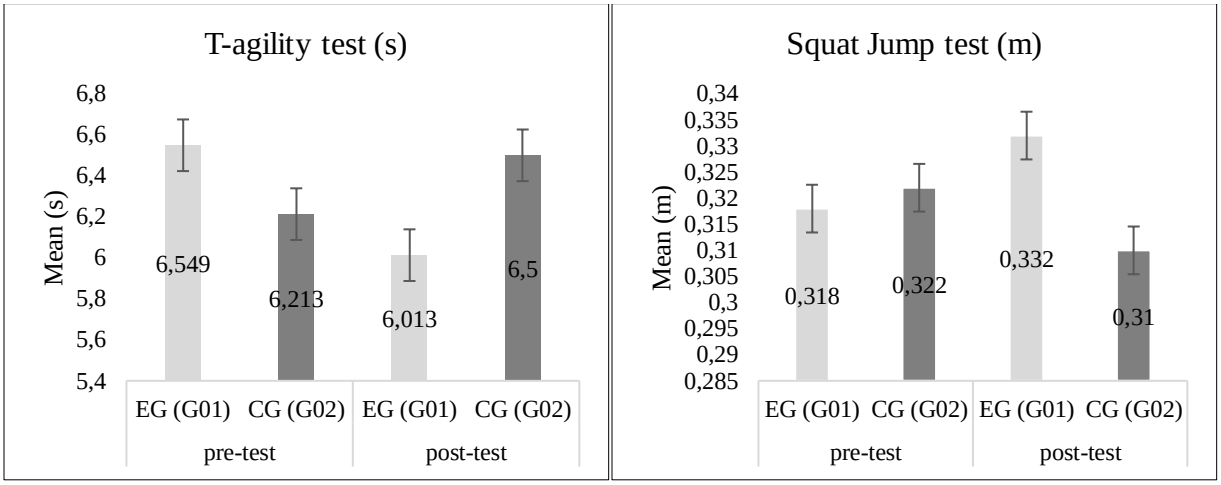

Figure 7. Comparison of the results of both groups (EG-CG) between the pre-test and post-test results in squat jump and agility performance.

DISCUSSION

This research aimed to assess the impact of a HIIT program featuring plyometric exercises on the physical performance of junior soccer players. The results indicate a significant enhancement in both jumping ability and change of direction performance among the intervention group after 10 weeks of HIIT training. Brief training intervals support the effectiveness of HIIT (Gillen et al., 2014), particularly since exercise modalities that engage a higher proportion of muscle fibres—especially Type II motor units—may yield distinct and positive outcomes that warrant further exploration (Farland et al., 2015). The observed improvements in jumping performance can be attributed to the stretch-shortening cycles involved in plyometric training. Existing literature suggests that explosive exercises can effectively enhance power (Fajrin & Kusnanik, 2018); (Chu & Myer, 2013). Additionally, studies have demonstrated that plyometric training on hard surfaces positively impacts jumping abilities (Ramírez-Campillo et al., 2013).

This study emphasizes the significance of high-intensity interval training (HIIT) combined with plyometric exercises to enhance jump efficiency among U19 football players. Players in the intervention group demonstrated superior jump efficiency and change of direction abilities, while control group players exhibited the lowest performance in jumping and agility. The synergistic effect of various plyometric exercises (including squat jumps, lateral jumps, vertical jumps, stride jumps, and hurdle jumps) produced better results than any single exercise alone. Consistent training, particularly focusing on both vertical and horizontal jumps, is crucial for improving jump performance, which is vital during football matches.

Developing maximal strength is essential for enhancing performance. HIIT training, characterized by intense physiological loads similar to those experienced in actual soccer games, typically maintains heart rates at around 85% of HRmax, with peaks reaching 90–95% of HRmax (Rebelo et al., 2014); (Mendez-Villanueva et al., 2013). Consequently, vertical jump performance is closely tied to maximal speed, strength, and explosive strength (Sheppard et al., 2008). Youth soccer players can benefit from supplementary training targeting these abilities (Lloyd & Oliver, 2012), as they lead to improved neuromuscular adaptations, including better coordination and rapid movements, enhancing jumping power. Previous research supports the positive effects of HIIT on jump performance. For instance, Tottori et Fujita (2019) reported a significant 9.6% improvement in standing long jump performance among children aged 9.7 years after a 7-week HIIT program conducted twice weekly (Tottori & Fujita, 2019). Linebach (2014) also found that increased explosive force in the lower limbs from HIIT workouts correlates with enhanced vertical jump performance (BENELGUEMAR et al., 2020). While these findings are promising, direct comparisons with other studies are challenging due to variations in participants' training backgrounds.

The significant increase in maximal power observed in footballers after ten weeks of high-intensity interval training (HIIT) with plyometric exercises can likely be attributed to enhanced drive control, stretch-shortening capacity, and musculoskeletal rigidity resulting from improved explosive strength in the legs (Bin Shamshuddin et al., 2020). Research consistently indicates that varied plyometric frequency training is effective for enhancing leg power (Fajrin & Kusnanik, 2018). This plays a crucial role in the effectiveness of such training programs, as the principle of overload is essential for improving muscular strength. It is important to acknowledge that body weight alone may not provide adequate resistance for optimal standing long jump performance; strength and power are vital components of jump ability (Sheppard et al., 2008).

The intensity of the plyometric exercises utilized in the study likely increased motor unit excitability and led to greater recruitment of fast-twitch muscle fibres, thereby enhancing jump performance. Additionally, plyometric exercises raise muscle temperature, which further amplifies muscle activation and supports the

storage and recoil of elastic energy in tendinous tissue (Ishikawa & Komi, 2004). Previous findings suggest that incorporating plyometric training can significantly improve key athletic performance components compared to traditional in-season training for young runners (Chelly et al., 2015). Furthermore, HIIT has been shown to markedly enhance power and performance in team sports (Iacono et al., 2015). Plyometric training over 16 weeks has also demonstrated improvements in power, as evidenced by tests such as the Multiple 5 Bounds and Standing Long Jump Test (Söhnlein et al., 2014). Researchers recommend the continuation of plyometric training to further develop explosive movements in athletes (Hammami et al., 2019). Given its efficacy, plyometric training is particularly relevant for sports requiring explosive jump movements (Söhnlein et al., 2014). When appropriately implemented, this type of training can yield benefits independent of an athlete's initial fitness level. In a related study, a short-term plyometric training program proved advantageous for high school male adolescents (age 16.89 ± 60.85) in enhancing explosive strength (SJ-testing). Plyometric exercises are widely recognized for their ability to improve explosive power (Ramírez-Campillo et al., 2013). Moreover, plyometric training is advantageous as it requires minimal space, time, and equipment. However, several studies have yet to definitively determine the optimal design for plyometric training, including considerations of frequency, volume, and landing height, to maximize muscle power enhancement (Ramírez-Campillo et al., 2013); (de Villarreal et al., 2009).

The current study highlights the significant enhancement in agility performance following a high-intensity interval training (HIIT) program that incorporated plyometric exercises in U19 football players. According to Cochrane et al. (2004), agility is primarily influenced by rapid movements, with power and strength playing a minimal role (Cochrane et al., 2004). Our findings support the hypothesis that plyometric exercises can effectively improve agility metrics. This is consistent with previous research indicating that HIIT programs featuring plyometric exercises result in improved agility times, as documented by (Chiu et al., 2004).

Plyometric exercises are widely utilized to boost explosive actions in soccer, offering the advantage of easy integration into training sessions due to their minimal spatial and equipment requirements. They also mimic the neuromuscular demands present in essential soccer activities such as sprinting, jumping, and changing direction (Gehri et al., 1998). Prior studies have shown that high-intensity plyometric exercises, like drop jumps, are safe and effective for young athletes, as noted by (Ramírez-Campillo et al., 2013); (Thomas et al., 2009). Improvements in power development, reactive strength, and eccentric strength likely contributed to enhanced agility performance (Randell et al., 2010); (Sheppard & Young, 2006). Although acceleration may depend more on a slower stretch-shortening cycle and the rate of power production, Thomas et al. (2009) found that sprint times remained unchanged even as agility improved by 9% over six weeks of plyometric training in semi-professional adolescent soccer players (Thomas et al., 2009). In children, a study by Meylan and Malatesta (2009) recorded a 10% enhancement in agility after eight weeks of plyometric training (Meylan & Malatesta, 2009). Miller et al. (2006) also reported improvements of 5% and 3% in the T-agility and Illinois agility tests, respectively, after six weeks of plyometric training (Miller et al., 2006). The research by bin Shamshuddin MH et al. (2020) further indicated that six weeks of plyometric training enhanced agility in recreational football players, with significant improvements observed in the intervention group ($p < .05$) while the control group's agility remained largely unchanged (Bin Shamshuddin et al., 2020). This study demonstrated a reduction in time for the T-test agility, supporting the notion that plyometric training can positively influence agility. While fewer studies have focused on the effects of plyometric training on individual endurance, the evidence supporting its impact on agility remains strong. Notably, Thomas et al (2009) documented a significant improvement in agility in semi-professional adolescent footballers after six weeks of plyometric training, despite no change in sprint performance (Thomas et al., 2009).

In summary, the 10-week HIIT program focused on jumping exercises for U19 soccer players led to notable improvements in explosive power and change of direction performance. While both high plyometric volume and a hard training surface positively influenced jump and agility outcomes, it was primarily the combination of high-volume training on a hard surface that enhanced jumping ability and directional changes after intense exercise, demonstrating its effectiveness for performance gains. Conversely, excessive training volume or the use of harder surfaces may hinder adaptations in maximum jump height or pure concentric strength (e.g., squat jump) when fast stretch-shortening cycle (SSC) actions are involved.

CONCLUSION

The HIIT (High-Intensity Interval Training) program was consistently scheduled weekly for all participants, ensuring homogeneity in terms of academic commitments and eliminating bias related to training timing or variations in regimens. This study demonstrates that a well-structured exercise program, grounded in scientific principles, can significantly enhance key physical components. The commitment to effectively executing the training program is crucial for maintaining its success.

The findings reveal improvements in explosive strength and agility performance after a 10-week HIIT regimen that incorporated plyometric exercises among U19 football players. These attributes—explosiveness and agility—are critical for enhancing athletic performance in sports. It is also important to explore varying intensities and volumes within the HIIT framework to identify the optimal conditions for training. This can assist coaches and physical trainers in planning effective training sessions over the 10-week period, as established in this study. Overall, these results offer valuable insights for refining training routines, aimed at boosting players' explosive power and agility before competitive matches.

Practical application

This research highlights that a High Intensity Interval Training (HIIT) program incorporating plyometric exercises is crafted with a scientific foundation and rigorously implemented. It serves as a crucial element of training for elite football players, with evidence supporting its effectiveness in enhancing explosive power and agility. Consequently, integrating this combined training regimen can enhance players' performance during matches while also reducing the risk of injuries.

To sustain the interest of young athletes, it is important to frequently modify and update the workouts. This approach will keep athletes engaged and motivated to adopt effective training methods.

AUTHOR CONTRIBUTIONS

This study was conducted by a group of researchers from the laboratory of motor learning and control, Institute of Sciences and Techniques of Physical and Sports Activities, Mohamed Boudiaf University, Algeria; composed of:

Laidi Abderrahim: The study utilized the Statistical Package for the Social Sciences (SPSS) to address specific research questions. We significantly contributed to the design of physical tests as well as the acquisition, analysis, and interpretation of data. The original research team was responsible for preparing and presenting the findings, which included reviewing and discussing revisions. Our approach involved comprehensive data collection and analysis using statistical techniques, with a focus on effective data presentation. We collectively agree to take responsibility for all aspects of this research, ensuring the accuracy and integrity of the work.

Djerioui Makhlouf: The study utilized the Statistical Package for the Social Sciences (SPSS) to address specific research questions. We significantly contributed to the design of physical tests as well as the acquisition, analysis, and interpretation of data. The original research team was responsible for preparing and presenting the findings, which included reviewing and discussing revisions. Our approach involved comprehensive data collection and analysis using statistical techniques, with a focus on effective data presentation. We collectively agree to take responsibility for all aspects of this research, ensuring the accuracy and integrity of the work.
Saadaoui Fayssal: The study utilized the Statistical Package for the Social Sciences (SPSS) to address specific research questions. We significantly contributed to the design of physical tests as well as the acquisition, analysis, and interpretation of data. The original research team was responsible for preparing and presenting the findings, which included reviewing and discussing revisions. Our approach involved comprehensive data collection and analysis using statistical techniques, with a focus on effective data presentation. We collectively agree to take responsibility for all aspects of this research, ensuring the accuracy and integrity of the work.
Khalil Bourenane: The study utilized the Statistical Package for the Social Sciences (SPSS) to address specific research questions. We significantly contributed to the design of physical tests as well as the acquisition, analysis, and interpretation of data. The original research team was responsible for preparing and presenting the findings, which included reviewing and discussing revisions. Our approach involved comprehensive data collection and analysis using statistical techniques, with a focus on effective data presentation. We collectively agree to take responsibility for all aspects of this research, ensuring the accuracy and integrity of the work.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

REFERENCES

Alricsson, M., Harms-Ringdahl, K., & Werner, S. (2001). Reliability of sports related functional tests with emphasis on speed and agility in young athletes. Scandinavian Journal of Medicine & Science in Sports, 11(4), 229-232. https://doi.org/10.1034/j.1600-0838.2001.110406.x

Aouichaoui, C., Trabelsi, Y., Bouhlel, E., Tabka, Z., Dogui, M., Richalet, J. P., & Buvry, A. B. (2012). The relative contributions of anthropometric variables to vertical jumping ability and leg power in Tunisian children. The Journal of Strength & Conditioning Research, 26(3), 777-788. https://doi.org/10.1519/JSC.0b013e31822a61a2

Arslan, E., Kilit, B., Clemente, F. M., Soylu, Y., Sögüt, M., Badicu, G., Akca, F., Gokkaya, M., & Murawska-Ciałowicz, E. (2021). The effects of exercise order on the psychophysiological responses, physical and technical performances of young soccer players: Combined small-sided games and high-intensity interval training. Biology, 10(11), 1180. https://doi.org/10.3390/biology10111180

Benelguemar, H., Bouabdellah, S., & Mouissi, F. (2020). The Kinematical Analysis of Blocking Skill in Volleyball and Their Relationships with the Explosive Force of Lower Limbs. International Journal of Sport, Exercise & Training Sciences, 73-79. https://doi.org/10.18826/useeabd.731462

Bin Shamshuddin, M. H., Hasan, H., Azli, M. S., Mohamed, M. N., & Razak, F. A. A. (2020). Effects of plyometric training on speed and agility among recreational football players. International Journal of Human Movement and Sports Sciences, 8(5), 174-180. https://doi.org/10.13189/saj.2020.080503

Buchheit, M., & Laursen, P. B. (2013a). High-intensity interval training, solutions to the programming puzzle: Part I: cardiopulmonary emphasis. Sports Medicine, 43(5), 313-338. https://doi.org/10.1007/s40279-013-0029-x

Buchheit, M., & Laursen, P. B. (2013b). High-intensity interval training, solutions to the programming puzzle: Part II: Anaerobic energy, neuromuscular load and practical applications. In Sports Medicine (Vol. 43, Issue 10, pp. 927-954). https://doi.org/10.1007/s40279-013-0066-5

Burgomaster, K. A., Heigenhauser, G. J. F., & Gibala, M. J. (2006). Effect of short-term sprint interval training on human skeletal muscle carbohydrate metabolism during exercise and time-trial performance. Journal of Applied Physiology, 100(6), 2041-2047. https://doi.org/10.1152/japplphysiol.01220.2005

Burgomaster, K. A., Hughes, S. C., Heigenhauser, G. J. F., Bradwell, S. N., & Gibala, M. J. (2005). Six sessions of sprint interval training increases muscle oxidative potential and cycle endurance capacity in humans. Journal of Applied Physiology. https://doi.org/10.1152/japplphysiol.01095.2004

Cavagna, G. A. (1977). Storage and utilization of elastic energy in skeletal muscle. Exercise and Sport Sciences Reviews, 5(1), 89-130. https://doi.org/10.1249/00003677-197700050-00004

Chelly, M. S., Ghenem, M. A., Abid, K., Hermassi, S., Tabka, Z., & Shephard, R. J. (2010). Effects of in-season short-term plyometric training program on leg power, jump-and sprint performance of soccer players. The Journal of Strength & Conditioning Research, 24(10), 2670-2676. https://doi.org/10.1519/JSC.0b013e3181e2728f

Chelly, M. S., Hermassi, S., & Shephard, R. J. (2015). Effects of in-season short-term plyometric training program on sprint and jump performance of young male track athletes. The Journal of Strength & Conditioning Research, 29(8), 2128-2136. https://doi.org/10.1519/JSC.0000000000000860

Chiu, L. Z. F., Fry, A. C., Schilling, B. K., Johnson, E. J., & Weiss, L. W. (2004). Neuromuscular fatigue and potentiation following two successive high intensity resistance exercise sessions. European Journal of Applied Physiology, 92, 385-392. https://doi.org/10.1007/s00421-004-1144-z

Chu, D. A., & Myer, G. (2013). Plyometrics. Human kinetics. https://doi.org/10.5040/9781718225459

Cochrane, D. J., Legg, S. J., & Hooker, M. J. (2004). The short-term effect of whole-body vibration training on vertical jump, sprint, and agility performance. The Journal of Strength & Conditioning Research, 18(4), 828-832. https://doi.org/10.1519/14213.1

de Villarreal, E. S.-S., Kellis, E., Kraemer, W. J., & Izquierdo, M. (2009). Determining variables of plyometric training for improving vertical jump height performance: a meta-analysis. The Journal of Strength & Conditioning Research, 23(2), 495-506. https://doi.org/10.1519/JSC.0b013e318196b7c6

Delecluse, C., Van Coppenolle, H., Willems, E., Van Leemputte, M., Diels, R., & Goris, M. (1995). Influence of high-resistance and high-velocity training on sprint performance. Medicine and Science in Sports and Exercise, 27(8), 1203-1209. https://doi.org/10.1249/00005768-199508000-00015

Endab, J. P. D. (2024). Effectiveness of Squat and Countermovement Jumps in Improving Vertical Jump Performance. British Journal of Multidisciplinary and Advanced Studies, 5(3), 69-95. https://doi.org/10.37745/bjmas.2022.04101

Fajrin, F., & Kusnanik, N. W. (2018). Effects of high intensity interval training on increasing explosive power, speed, and agility. Journal of Physics: Conference Series, 947(1), 012045. https://doi.org/10.1088/1742-6596/947/1/012045

Farland, C. V, Schuette, J., Foster, C., Porcari, J. P., Doberstein, S. T., Harbin, M., Guidotti, F., Roberts, B., & Tuuri, A. (2015). The effects of high intensity interval training versus steady state training on aerobic and anaerobic capacity. Medicine & Science in Sports & Exercise, 47(5S), 133. https://doi.org/10.1249/01.mss.0000476771.63318.52

Gehri, D. J., Ricard, M. D., Kleiner, D. M., & Kirkendall, D. T. (1998). A comparison of plyometric training techniques for improving vertical jump ability and energy production. Journal of Strength and Conditioning Research, 12, 85-89. https://doi.org/10.1519/00124278-199805000-00005

Gibala, M. J., & Jones, A. M. (2013). Physiological and performance adaptations to high-intensity interval training. Limits of Human Endurance, 76, 51-60. https://doi.org/10.1159/000350256

Gillen, J. B., & Gibala, M. J. (2014). Is high-intensity interval training a time-efficient exercise strategy to improve health and fitness? Applied Physiology, Nutrition, and Metabolism, 39(3), 409-412. https://doi.org/10.1139/apnm-2013-0187

Gillen, J. B., Percival, M. E., Skelly, L. E., Martin, B. J., Tan, R. B., Tarnopolsky, M. A., & Gibala, M. J. (2014). Three minutes of all-out intermittent exercise per week increases skeletal muscle oxidative capacity and improves cardiometabolic health. PloS One, 9(11), e111489. https://doi.org/10.1371/journal.pone.0111489

Hammami, M., Gaamouri, N., Aloui, G., Shephard, R. J., & Chelly, M. S. (2019). Effects of combined plyometric and short sprint with change-of-direction training on athletic performance of male U15 handball players. The Journal of Strength & Conditioning Research, 33(3), 662-675. https://doi.org/10.1519/JSC.0000000000002870

Iacono, A. Dello, Eliakim, A., & Meckel, Y. (2015). Improving fitness of elite handball players: small-sided games vs. high-intensity intermittent training. The Journal of Strength & Conditioning Research, 29(3), 835-843. https://doi.org/10.1519/JSC.0000000000000686

Ishikawa, M., & Komi, P. V. (2004). Effects of different dropping intensities on fascicle and tendinous tissue behavior during stretch-shortening cycle exercise. Journal of Applied Physiology, 96(3), 848-852. https://doi.org/10.1152/japplphysiol.00948.2003

Jiménez-Maldonado, A., Rentería, I., García-Suárez, P. C., Moncada-Jiménez, J., & Freire-Royes, L. F. (2018). The impact of high-intensity interval training on brain derived neurotrophic factor in brain: a mini-review. Frontiers in Neuroscience, 12, 839. https://doi.org/10.3389/fnins.2018.00839

Kemi, O. J., & Wisløff, U. (2010). High-Intensity Aerobic Exercise Training Improves the Heart in Health and Disease. In / Journal of Cardiopulmonary Rehabilitation and Prevention (Vol. 30). https://doi.org/10.1097/HCR.0b013e3181c56b89

Laursen, P., & Buchheit, M. (2019). Science and application of high-intensity interval training. Human kinetics. https://doi.org/10.5040/9781492595830

Lloyd, R. S., & Oliver, J. L. (2012). The youth physical development model: A new approach to long-term athletic development. Strength & Conditioning Journal, 34(3), 61-72. https://doi.org/10.1519/SSC.0b013e31825760ea

Martínez-Rodríguez, A., Rubio-Arias, J. A., García-De Frutos, J. M., Vicente-Martínez, M., & Gunnarsson, T. P. (2021). Effect of high-intensity interval training and intermittent fasting on body composition and physical performance in active women. International Journal of Environmental Research and Public Health, 18(12), 6431. https://doi.org/10.3390/ijerph18126431

Mendez-Villanueva, A., Buchheit, M., Simpson, B., & Bourdon, P. C. (2013). Match play intensity distribution in youth soccer. International Journal of Sports Medicine, 34(02), 101-110. https://doi.org/10.1055/s-0032-1306323

Meylan, C., & Malatesta, D. (2009). Effects of in-season plyometric training within soccer practice on explosive actions of young players. The Journal of Strength & Conditioning Research, 23(9), 2605-2613. https://doi.org/10.1519/JSC.0b013e3181b1f330

MH, H., Khan, M. H., Tanwar, T., Irshad, N., & Nuhmani, S. (2021). Acute effects of weighted plyometric exercise on sprint, agility and jump performance in university football players. Physical Activity Review, 1(9), 1-8. https://doi.org/10.16926/par.2021.09.01

Miller, M. G., Herniman, J. J., Ricard, M. D., Cheatham, C. C., & Michael, T. J. (2006). The effects of a 6-week plyometric training program on agility. In ©Journal of Sports Science and Medicine (Vol. 5).

Monteiro, W. D., Simão, R., Polito, M. D., Santana, C. A., Chaves, R. B., Bezerra, E., & Fleck, S. J. (2008). Influence of strength training on adult women's flexibility. The Journal of Strength & Conditioning Research, 22(3), 672-677. https://doi.org/10.1519/JSC.0b013e31816a5d45

Naves, J. P. A., Viana, R. B., Rebelo, A. C. S., De Lira, C. A. B., Pimentel, G. D., Lobo, P. C. B., De Oliveira, J. C., Ramirez-Campillo, R., & Gentil, P. (2018). Effects of high-intensity interval training vs. sprint interval training on anthropometric measures and cardiorespiratory fitness in healthy young women. Frontiers in Physiology, 9, 1738. https://doi.org/10.3389/fphys.2018.01738

Oliveira-Junior, A., Casimiro-Lopes, G., Donangelo, C. M., Koury, J. C., Farinatti, P. V., Massuça, L. M., & Fragoso, I. (2017). Métodos de Evaluación de la Maduración Biológica en Jugadores Adolescentes de Fútbol Considerando el Estado de Zinc. International Journal of Morphology, 35(4), 1607-1613. ISSN 0717-9502. https://doi.org/10.4067/S0717-95022017000401607

Ozbar, N., Ates, S., & Agopyan, A. (2014). The effect of 8-week plyometric training on leg power, jump and sprint performance in female soccer players. The Journal of Strength & Conditioning Research, 28(10), 2888-2894. https://doi.org/10.1519/JSC.0000000000000541

Ramírez-Campillo, R., Andrade, D. C., & Izquierdo, M. (2013). Effects of plyometric training volume and training surface on explosive strength. The Journal of Strength & Conditioning Research, 27(10), 2714-2722. https://doi.org/10.1519/JSC.0b013e318280c9e9

Randell, A. D., Cronin, J. B., Keogh, J. W. L., & Gill, N. D. (2010). Transference of strength and power adaptation to sports performance-horizontal and vertical force production. Strength & Conditioning Journal, 32(4), 100-106. https://doi.org/10.1519/SSC.0b013e3181e91eec

Raya, M. A., Gailey, R. S., Gaunaurd, I. A., Jayne, D. M., Campbell, S. M., Gagne, E., Manrique, P. G., Muller, D. G., & Tucker, C. (2013). Comparison of three agility tests with male servicemembers: Edgren Side Step Test, T-Test, and Illinois Agility Test. Journal of Rehabilitation Research & Development, 50(7). https://doi.org/10.1682/JRRD.2012.05.0096

Rebelo, A., Brito, J., Seabra, A., Oliveira, J., & Krustrup, P. (2014). Physical match performance of youth football players in relation to physical capacity. European Journal of Sport Science, 14, S148-S156. https://doi.org/10.1080/17461391.2012.664171

Reilly, T., Williams, A. M., Nevill, A., & Franks, A. (2000). A multidisciplinary approach to talent identification in soccer. Journal of Sports Sciences, 18(9), 695-702. https://doi.org/10.1080/02640410050120078

Ribeiro, J., Teixeira, L., Lemos, R., Teixeira, A. S., Moreira, V., Silva, P., & Nakamura, F. Y. (2020). Effects of plyometric versus optimum power load training on components of physical fitness in young male soccer players. International Journal of Sports Physiology and Performance, 15(2), 222-230. https://doi.org/10.1123/ijspp.2019-0039

Rosenblat, M. A., Perrotta, A. S., & Thomas, S. G. (2020). Effect of high-intensity interval training versus sprint interval training on time-trial performance: a systematic review and meta-analysis. Sports Medicine, 50, 1145-1161. https://doi.org/10.1007/s40279-020-01264-1

Ruiz, J. R., Sui, X., Lobelo, F., Morrow, J. R., Jackson, A. W., Sjöström, M., & Blair, S. N. (2008). Association between muscular strength and mortality in men: prospective cohort study. Bmj, 337. https://doi.org/10.1136/bmj.a439

Sheppard, J. M., Cronin, J. B., Gabbett, T. J., McGuigan, M. R., Etxebarria, N., & Newton, R. U. (2008). Relative importance of strength, power, and anthropometric measures to jump performance of elite volleyball players. The Journal of Strength & Conditioning Research, 22(3), 758-765. https://doi.org/10.1519/JSC.0b013e31816a8440

Sheppard, J. M., & Young, W. B. (2006). Agility literature review: Classifications, training and testing. Journal of Sports Sciences, 24(9), 919-932. https://doi.org/10.1080/02640410500457109

Söhnlein, Q., Müller, E., & Stöggl, T. L. (2014). The effect of 16-week plyometric training on explosive actions in early to mid-puberty elite soccer players. The Journal of Strength & Conditioning Research, 28(8), 2105-2114. https://doi.org/10.1519/JSC.0000000000000387

Thomas, K., French, D., & Hayes, P. R. (2009). The effect of two plyometric training techniques on muscular power and agility in youth soccer players. The Journal of Strength & Conditioning Research, 23(1), 332-335. https://doi.org/10.1519/JSC.0b013e318183a01a

Tottori, N., & Fujita, S. (2019). Effects of plyometric training on sprint running performance in boys aged 9-12 years. Sports, 7(10), 219. https://doi.org/10.3390/sports7100219

Tschakert, G., Kroepfl, J., Mueller, A., Moser, O., Groeschl, W., & Hofmann, P. (2015). How to regulate the acute physiological response to "aerobic" high-intensity interval exercise. Journal of Sports Science & Medicine, 14(1), 29.

Váczi, M., Tollár, J., Meszler, B., Juhász, I., & Karsai, I. (2013). Short-term high intensity plyometric training program improves strength, power and agility in male soccer players. Journal of Human Kinetics, 36, 17. https://doi.org/10.2478/hukin-2013-0002

Weston, K. S., Wisløff, U., & Coombes, J. S. (2014). High-intensity interval training in patients with lifestyle-induced cardiometabolic disease: a systematic review and meta-analysis. British Journal of Sports Medicine, 48(16), 1227-1234. https://doi.org/10.1136/bjsports-2013-092576

Wisløff, U., Ellingsen, K., & Kemi, O. J. (2009). High-Intensity Interval Training to Maximize Cardiac Benefits of Exercise Training? In Exerc. Sport Sci. Rev (Vol. 37, Issue 3). https://doi.org/10.1097/JES.0b013e3181aa65fc

SUSTAINABILITY & SPORTS SCIENCE JOURNAL

ORIGINAL ARTICLE

Comparative analyses of implementation of connected sensors on heart rate variability in middle school judo athletes versus non-athletes

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ABSTRACT

Purpose: This study aimed to examine the differences in heart rate variability (HRV) between athlete and non-athlete students in middle school using unimplemented sensor heart rate. Materials and Methods: Sixty-seven judo athlete and non-judo-athlete students were recruited to the study from middle school were divided into experimental groups (n = 39, height 162.4 ± 7.6 cm, weight 52.7 ± 6.3 kg, Age 12.8 ± 1.3 years), and Control group student (n = 37, height 159.1 ± 6.9 cm, weight 53.2 ± 7.3 kg, age 13.2 ± 0.8 years),The CG students did not take part in any competitive sport at any level, Measure mean heart rate (Mean HR), mean R-R, standard deviation of all normal R-R intervals; (SDNN) and relative, root of the mean squared differences of successive RR intervals (RMSSD),low-frequency (LF), high-frequency (HF) and low-frequency ratio (LF/HF) indicators were used. The T-tests was used to compare sports teams with general differences between athlete and non-judo-athlete students. The significance level was set at $p < .05$. Results: HRV analysis software analyses the (RR) interval time domain components and the results were given as standard deviation of RR intervals (SDNN), square root of the mean of the sum of the squares of differences between adjacent RR intervals (RMSSD), adjacent RR interval differing more than 50ms (NN50), The Mean (iRR) of the EG is significantly higher than that of the average CG ($t = 2.245$, $p < .05$); in terms of Mean HR, the EG are significantly lower than the average CG ($t = -2.149$, $p < .05$). Conclusion: Judo training and combat field exercises utilising connected sensors are effective for middle-aged individuals, helping to maintain and reduce resting heart rate while enhancing cardiopulmonary function.

Keywords: Health, Judo, Combat field, Heart rate, Variability, Middle school.

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INTRODUCTION

Variability in beat-by-beat heart period is an intrinsic characteristic of healthy cardiac functioning (Draghici & Taylor, 2016), (Vigo, Siri, & Cardinali, 2019) observed that the arterial pressure during the respiratory cycle and the time between heartbeats were variability. When the heart beats, it does not beat at a fixed speed, and there is a small gap within tens of milliseconds between a normal heartbeat and a heartbeat. several studies by (Freeman, Dewey, Hadley, Myers, & Froelicher, 2006; Fu & Levine, 2013; Hautala, Kiviniemi, & Tulppo, 2009; Iellamo, Volterrani, Di Gianfrancesco, Fossati, & Casasco, 2018) pointed out that although the heart beats regularly due to the discharge of the sinus node of the right atrium, the discharge of this sinus node is affected by the autonomic nervous system. The sympathetic nervous system accelerates the discharge rate of the sinus node, thereby increasing the heart rate (Zhou et al., 2016). The parasympathetic nervous system inhibits the discharge rate of the sinus node, and the heart rate slows down (Sztajzel, 2004). Due to the difference between the sympathetic nervous system and the parasympathetic nervous system (Hinojosa-Laborde, Chapa, Lange, & Haywood, 1999; Rowe & Troen, 1980) Mutual antagonism causes the frequency of sinoatrial node discharge to be differently regulated by the autonomic nervous system (Rocchetti, Malfatto, Lombardi, & Zaza, 2000), which makes the heart beat show different degrees of variability called heart rate variability (HRV) (Lehrer & Gevirtz, 2014; Shaffer & Ginsberg, 2017). Heart rate variability can be analysed by electrocardiogram. On the electrocardiogram, the R wave is a more significant waveform that is easy to be detected (Bansal, Khan, & Salhan, 2009; Selvaraj, Jaryal, Santhosh, Deepak, & Anand, 2008). The R interval represents the rate of the heartbeat. Therefore, the RR interval (RRI) is most often used to represent the heartbeat interval (such as Figure 1). Heart rate variability analysis can be divided into time domain analysis and frequency domain analysis (Kuss, Schumann, Kluttig, Greiser, & Haerting, 2008).

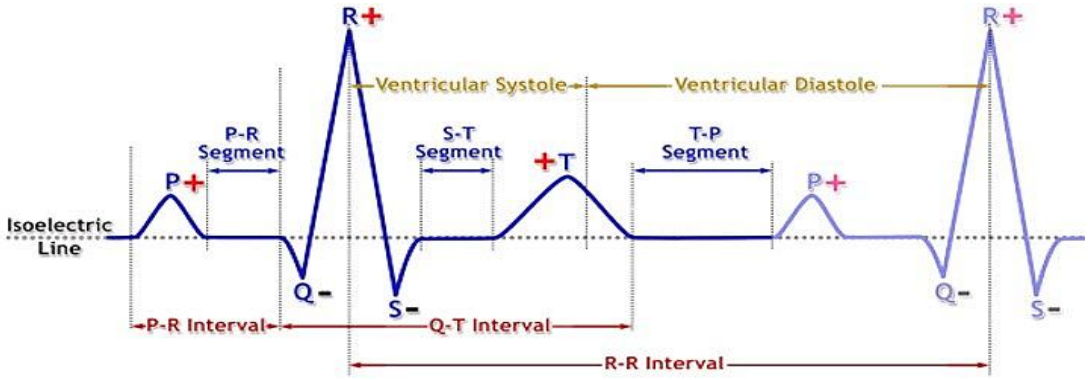

Figure 1. The interval between adjacent R waves is RR interval (RRI).

Early heart rate variability analysis is mostly used in clinical medicine, and the autonomic nerve control mechanism can be used to obtain evaluation data from this analysis. Various parameters of heart rate variability can be used to determine the pros and cons of heart function. A study by Yan Wang and Jun Xu (Yan, Jun, & Guo-Rong, 2006) pointed out that changes in some parameters of heart rate variability can be used as reference indicators for judging the severity and prognosis of patients with chronic heart failure. Cannon Christopher (Cannon et al., 2001) believe that the continuous measurement of heart rate variability should be regarded as indispensable in the care after complete coronary artery bypass surgery.

In addition to clinical medicine, heart rate variability has also been widely used in sports science research in recent years. In addition to explore the impact of exercise training on heart rate variability, heart rate variability

it was often used to test the effectiveness of sports training (Sandercock, Bromley, & Brodie, 2005). Aubert et al., (2003) noted that the heart rate variability is used to evaluate the impact of different pace methods on sports performance (Manar, Adel, Lalia, & Saddak, 2023). The application of heart rate variability in sports is mainly to evaluate the activity of the autonomic nervous system (sympathetic and parasympathetic nerve) through various indicators to measure the effect of sports training or sports performance. The increase in sympathetic activity is conducive to coping with emergencies; the activity of parasympathetic nerves is better, for sports that require high concentration, it is conducive to achieving better results, and at the same time, it can recover faster after exercise (Makivić, Nikić Djordjević, & Willis, 2013). Many studies have shown that exercise has the effect of improving heart rate variability (Borresen & Lambert, 2008; Lehrer & Gevirtz, 2014; Sandercock et al., 2005; Wheat & Larkin, 2010). Makivić et al (Makivić et al., 2013) pointed out that the index of heart rate variability is helpful for sports performance and anxiety control during competition. (Tang et al., 2009) stated that the analysis of heart rate variability of gymnastics students in sitting, resting and inverted upside down showed that they have better autonomic nervous system regulation. (Aubert et al., 2003) mentioned that the heart rate variability of non-athletes is lower than that of athletes (Belkadi, Alia, & Mohammed, 2020).

Exercise can improve the activity of the heart's autonomic nervous system. If engaged in long-term, high-intensity or endurance sports training, it can increase heart rate variability and reduce the risk of cardiovascular disease (Boudehri, Belkadi, Dahoune, & Atallah, 2023); There is no significant difference in short-term and medium-intensity sports training. Regarding the effect of long-term exercise training on heart rate variability in the past, (Cherara, Belkadi, Mesaliti, & Beboucha, 2022) pointed out that they have been engaged in exercise training for a long time. Elderly males aged 13 to 15 years have better vague nerve and sympathy Nerve control ability. (Deus et al., 2019) Aimed at average practice Middle-aged and elderly people who practiced 3 times a week for at least 1 hour each time and the general group of the same age conducted research. The results pointed out that the short-term effect of (Adel et al., 2019) on middle-aged and elderly people is to reduce their sympathetic nerve activity and increase their parasympathetic nerve activity; The long-term effect is to enhance sympathetic nerve activity without affecting parasympathetic nerve activity. (Romanchuk & Dolgier, 2021) explored the effects of prolonged aerobic exercise on middle-aged women. The results of the study showed that continuous aerobic exercise for 3-5 years, 3 times a week, can increase sympathetic nerve activity and reduce their parasympathetic nerve activity.

Regarding the impact of short-term exercise training in the past on heart rate variability, after 8 weeks of shooting training, (Thayer, Hansen, Saus-Rose, & Johnsen, 2009) showed significant relationship among cognitive performance, HRV, and prefrontal neural function that has important implications for both physical and mental health. However, some studies believe that exercise cannot change heart rate variability. Ladawan et al., (2017) pointed out that 12 weeks of mid-intensity aerobic exercise improved attention, brain processing speed, blood pressure and maximal workload in healthy middle-aged subjects. (Jurca, Church, Morss, Jordan, & Earnest, 2004) discussed the effects of 8-week aerobic exercise intervention on cardiorespiratory endurance and heart rate variability (Benhammou et al., 2022). The results also showed that short-term, medium-intensity segmented exercise training had the same effect as continuous exercise training, but none Method to improve the heart rate variability of college students. (Del Rosso, Nakamura, & Boullosa, 2017; Hautala et al., 2003) showed that after anaerobic high-intensity exercise, the parasympathetic nerve activity of football players was lower than that of college physical education students, and there was no difference between the two after aerobic exercise (Beboucha, Belkadi, Benchehida, & Bengoua, 2021). Most of the early applications and researches on heart rate variability have appeared in the clinical medicine of middle-aged and elderly people. In recent years, the instruments have become more advanced, easy to operate and easy to obtain, which makes scholars more willing to turn the research objects

to young children. (Yeh & Kuo, 2012) studied the influence of Wii Sports sports mode on energy expenditure and heart rate variability of elementary and elementary school children. Among them, the index of heart rate variability of boxing is significantly higher than that of baseball and tennis. (Kraama, 2013) carried out 8-week cycling and aerobic training for 13 to 15-year-old children. The results of the study indicated that these physical training had no significant effect on heart rate variability. (Gamelin et al., 2009) performed 7 weeks of high-intensity interval exercise training on 38 children aged 8 to 11, and found that there was no significant difference in the heart rate variability indicators between the sports team group and the general school child group (Belkadi et al., 2015). The above studies are all aimed at children in elementary and middle schools, observing the effect of exercise intervention on heart rate variability. In view of the fact that training is essentially a physical and mental exercise stimulation, Based on the existing literature, the training time of less than 8 weeks seems to be too short to cause adaptation. (Cornelissen, Verheyden, Aubert, & Fagard, 2010; Gamelin et al., 2009; Jurca et al., 2004; Kraama, 2013), the effects of exercise on HRV are mostly insignificant, and the results of many studies are not consistent; Training intervention seems to have a more significant impact on HRV (Jurca et al., 2004; Romanchuk & Dolgier, 2021; Scheer, Siebrant, Brown, Shaw, & Shaw, 2014). Therefore, this study aims to clarify the influence of heart rate variability between the middle school team players and ordinary school children engaged in long-term sports training, in order to provide reference for sports trainers during the sports Saison.

MATERIAL AND METHODS

Study group

Seventy-six athlete and non-athlete students were recruited for the study from middle school and were divided into two groups: the experimental group (EG) consisting of 39 athletes (height 162.4 ± 7.6 cm, weight 52.7 ± 6.3 kg, age 12.8 ± 1.3 years) and the control group (CG) comprising 37 non-athletes (height 159.1 ± 6.9 cm, weight 53.2 ± 7.3 kg, age 13.2 ± 0.8 years). The EG students participated in a wide range of competitive sports at various levels, including football, athletics, swimming, martial arts, and handball. They had received sports training for more than six months, engaging in 90 minutes of basic physical fitness and sports training from Sunday to Wednesday. In contrast, the CG students did not participate in any competitive sports at any level.

Before the experiment, the protocol was explained to the participants and their parents or legal guardians. They were asked to fill out the "*Subject and Parents Consent Form*" and the "*Subject's Basic Information and Health Status Questionnaire*".

Procedure/Test protocol

Before conducting the study, it was stated in the consent form signed by the subjects and their parents that "*the subjects should not eat any irritating food, such as tea, coffee, etc., the night before, and keep their mood stable*.", and invite the subjects to enter the test Do not talk to people after the location to avoid affecting the heart rate variability data obtained in the experiment. Before the test, the subjects lie down for 10 minutes before testing and then put on a pulse sensor (Pulse sensor, World Famous Electronics llc., USA) on the left middle finger. The application Processing-3.3 monitors the heartbeat and then opens the application arduino-1.8.0-windows to collect 10 minutes of ECG data, with a sampling frequency of 100 times per second (Figure 2).

The ECG data collected by Arduino is compiled into Kubios HRV heart rate variability analysis software (Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014) through MATLAB R2015b to read the format, and then input the Kubios HRV program to generate heart rate variability data (e.g. Figure 3).

Figure 2. Heart rate variability measurement and signal acquisition.

Figure 3. Data generated by Kubios HRV heart rate variability analysis software.

The parameters of heart rate variability adopted in this research was carried similar to (Makivić et al., 2013).

Time domain analysis

The analysis method is to detect the interval of each QRS complex wave in the continuous ECG. The adjacent R waves represent the cycle of the heartbeat. This interval is the RR interval, and the continuous interval formed by the continuous RR interval is Represents the variability of heart rate (Sharma, Subramanian, Arunachalam, & Rajendran, 2015).

- Mean RRI: The average value of the heartbeat interval, an indicator of overall heart rate variability.
- SDNN: The standard deviation of the normal heartbeat interval, that is, the square root of the variance.
- Mean HR: The average number of heart beats per minute.
- RMSSD: The root mean square of the sum of squares of the difference between adjacent normal heartbeats.
- pNN50%: The ratio of the difference between adjacent normal heartbeats exceeding 50 milliseconds. The number of normal heartbeats with a difference of more than 50 milliseconds divided by the total number of heartbeat intervals.

Frequency domain analysis

The commonly used calculation method is fast Fourier transformation (FFT), which analyses the distribution of power (the variance) at various frequencies.

- Low frequency power (LF): The captured frequency is 0.04 ~ 0.15 Hz refers to the variation of the normal heartbeat interval in the low frequency range and represents the sympathetic nerve activity or the index of the simultaneous regulation of sympathetic nerve and parasympathetic nerve.
- High frequency power (HF): The captured frequency is 0.15 ~ 0.4 Hz refers to the variance of the normal heartbeat interval in the high frequency range and represents an indicator of parasympathetic nerve activity.
- Low and high frequency power ratio LF/HF: An indicator that reflects the balance of sympathetic and parasympathetic nerves or represents the condition of sympathetic nerve regulation.

Data collection and analysis

The data measured in the experiment are statistically analysed with SPSS 22.0, descriptive statistics present the basic data values of the subjects; independent sample t test analysis is used to compare whether the experimental group and the control group have significant differences in heart rate variability, and the significance level is $p < .05$ was considered.

RESULTS

The time domain analysis is shown in Table 1. The results show that the experimental group and the control group have significant differences in Mean iRR and Mean HR, while the other indicators are not significant. The Mean iRR of the elementary school sports team players is significantly higher than that of the average school children ($t = 2.245$, $p < .05$); in terms of Mean HR, the elementary school sports team players are significantly lower than the average school children ($t = -2.149$, $p < .05$). The results of frequency domain analysis are shown in Table 2. The results show that there is no significant difference between the two groups in the low frequency (LF), high frequency (HF), and low frequency/high frequency (LF/HF) indicators.

Table 1. Comparison of time domain analysis of heart rate variability between experimental group and control group.

	Experimental group (n = 39)		**Control group (n = 37)**		***t* Value**	**Obs.**
	M	SD	M	SD		
Mean RRI(ms)	805.12	4	746.64	81.65	2.245*	Experimental＞Control
SDNN(ms)	95.82	38.22	91.40	43.96	.491	
Mean HR	78.55	9.57	82.95	9.03	-2.149*	Control＞Experimental
RMSSD (ms)	86.75	42.70	84.47	46.90	.232	
pNN50(%)	31.19	19.90	30.256	17.76	.223	

*Note. *p < .05.*

Table 2. Comparison of the time domain analysis of heart rate variability between the experimental group and the control group.

	Experimental group (n = 39)		**Control group (n = 37)**		***t Value***
	M	SD	M	SD	
LF	2790.93	3415.44	3887.80	6227.54	***-1.010***
HF	2419.00	2483.05	3153.83	3502.45	***-1.112***
LF/HF	***1.30***	***0.70***	***1.13***	***0.72***	***1.081***

*Note. *p < .05.*

DISCUSSION

From the results of this study, it is found that the Mean RRI and Mean HR of the upper-grade students in elementary school after more than half a year of exercise training are significantly better than those of the untrained students; other time-domain analysis indicators SDNN, RMSSD, and pNN50 are between the two groups Although there is no significant difference, there is a trend that the experimental group is better than the control group. Both the longer Mean RRI and the lower Mean HR show that the trained children have better cardiorespiratory fitness. This result is consistent with many previous studies. The research results of (Draghici & Taylor, 2016; Iellamo et al., 2018; Levy et al., 1998; Sztajzel, 2004) point out that whether it is explosive or the average heart rate of endurance athletes was significantly higher than that of the control group, and the average heart rate of both athletes was significantly lower than that of non-athletes, especially for endurance athletes. Athletes have the lowest heart rate. This result is also consistent with the results of (Aubert et al., 2003; Buchheit, Simon, Piquard, Ehrhart, & Brandenberger, 2004; Deus et al., 2019; Romanchuk & Dolgier, 2021) showing that exercise can produce a quiet heartbeat slowdown. In addition, this study found that the other time domain indicators (SDNN, RMSSD, pNN50) of the sports team group tended to be better than those of the general schoolchild group. RMSSD and pNN50 have a high correlation (Vanderlei, Silva, Pastre, Azevedo, & Godoy, 2008), which is used to estimate the function of the parasympathetic nerve and show the movement. The parasympathetic nerve function of the representative team group tends to be better than that of the general school children group. Based on the results of the frequency domain analysis of this study, the three indicators of LH, HF and LF/HF did not reach significant differences between the experimental group and the control group. Judging from a number of previous papers on heart rate variability with healthy school children as subjects (Gamelin et al., 2009; Hautala et al., 2003; Joyner, Charkoudian, & Wallin, 2008; Kraama, 2013), exercise training has no significant effect on the frequency domain analysis indicators of school children. The results of this study are roughly in line with these documents. Mandigout et al., (Mandigout et al., 2002) targeted 19 children aged 10-11 For 13 weeks of running endurance training, in the frequency domain analysis of the sports team group, there is no significant difference between LF and HF and the general schoolchild group. The researchers believe that endurance training has a positive effect on the aerobic capacity of healthy pre-adolescent children (Bansal et al., 2009; Kraama, 2013), but Will not cause changes in sympathetic and parasympathetic nerves. The results of (Del Rosso et al., 2017; Hautala et al., 2003) showed that after anaerobic high-intensity exercise, the parasympathetic nerve activity of football players was lower than that of college physical education students (Saddek et al., 2020; Senouci, Asli, Belkadi, Bouhella, & Koutchouk, 2024), which involved short high-intensity activities stressing both aerobic and anaerobic metabolic pathways.

There is no difference in regulation. Sacknoff, Gleim, Stachenfeld, and Coplan (Sacknoff, Gleim, Stachenfeld, & Coplan, 1994) studied 12 athletes and 18 non-athletes and found that the time domain of athletes' heart rate variability is greater than that of non-athletes, while the total energy and high-frequency power are less than non-athletes. Observed in non-athletes; The correlation between time domain and frequency domain is not observed in athletes, because This researcher believes that the index of heart rate variability in the frequency domain cannot accurately assess the activity of the parasympathetic nerve of the athlete's heart. Oliveira, Barker, Wilkinson, Abbott, and Williams (Manar et al., 2023; Oliveira, Barker, Wilkinson, Abbott, & Williams, 2017) conducted a systematic and comprehensive analysis of relevant literature to explore the relationship between HRV, physical activity, and cardiopulmonary function in children and adolescents.

Correlation between indicators of frequency domain analysis

The results of the above-mentioned literature on heart rate variability of school children are mostly consistent with the results of this study, but there are also some research results that show that exercise intervention

can significantly increase the heart rate variability. There are many literatures on the significant heart rate variability of adults after interventional exercises, especially many studies on middle-aged and elderly people or patients with heart disease as subjects (Belkadi et al., 2025; Benchehida et al., 2021; Yacine et al., 2020). After long-term exercise training, regardless of the type of exercise training, aerobic exercise or resistance exercise seems to have resulted in an increase in HRV (Romanchuk & Dolgier, 2021; Selig et al., 2004; Ueno & Moritani, 2003). This study is mainly aimed at children.

The insignificant reason may be that the heart rate variability of the children in the growth stage has not matured, although the control group has not exercised a long Training, but individual growth factors also have an effect on heart rate variability. Therefore, the heart rate variability changes of children's long-term exercise training are affected by age factors and are not easy to reach significant differences. Wu Rongzhou et al. (Rongzhou, 2011) conducted heart rate variability analysis on 750 healthy children, and found that regardless of the time domain analysis of SDNN, SDANN, PNNSO, RMSSD or the frequency domain analysis of TF, VLF, LF, HF, LF/HF and other indicators, There is a significant increase with age. It can be seen from previous related studies that the age-dependent changes in HRV may be related to the maturation process of the autonomic nervous system, and also to the increase in heart volume from infancy to adulthood (Benhammou, Mourot, Clemente, Coquart, & Belkadi, 2024; Kraama, 2013).

CONCLUSION

The conclusion of this study is that the quiet heart rate of regular training students in the upper grades of elementary school tug-of-war and the athletics team is significantly lower than that of ordinary school children. This shows that regular training or exercise can promote cardiorespiratory fitness. Parents and teachers should continue to promote and encourage school children to participate Sports. Compared with sports, the stimulation of growth and development is more likely to be an important factor affecting the HRV changes of school-age children. This may be the main reason for the small difference between the HRV of the sports team in this study and the general birth. The individual growth factors of elementary school children in China also have a considerable impact on the heart rate variability, so the heart rate variability involved in sports training is not likely to change significantly. This factor may be a limitation of this type of related research. In addition, although the subjects in this study are all children who have received sports training for more than half a year, there are still differences in training courses.

AUTHOR CONTRIBUTIONS

Moussa Mohammed: study design, data collection, data analysis, and manuscript preparation. Belkadi Adel: study design, data analysis, and manuscript preparation. Saddek Benhammou: data collection, data analysis. Abdelkader Dairi: study design, data analysis. Otmane Benbernou: data analysis, and manuscript preparation.

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REFERENCES

Adel, B., Abdelkader, B., Alia, C., Othman, B., Mohamed, S., & Houcin, A. (2019). The Effect of High-Intensity Exercise on Changes of Blood Concentration Components in Algerian National Judo Athletes. Acta Facultatis Educationis Physicae Universitatis Comenianae, 59(2). https://doi.org/10.2478/afepuc-2019-0013

Aubert, A. E., Seps, B., & Beckers, F. (2003). Heart rate variability in athletes. Sports medicine, 33(12), 889-919. https://doi.org/10.2165/00007256-200333120-00003

Bansal, D., Khan, M., & Salhan, A. K. (2009). A review of measurement and analysis of heart rate variability. 2009 International Conference on Computer and Automation Engineering, 243-246. IEEE. https://doi.org/10.1109/ICCAE.2009.70

Beboucha, W., Belkadi, A., Benchehida, A., & Bengoua, A. (2021). The anthropometric and physiological characteristics of young algerian soccer players. Acta Facultatis Educationis Physicae Universitatis Comenianae, 61(1). https://doi.org/10.2478/afepuc-2021-0004

Belkadi, A., Alia, C., & Mohammed, Z. (2020). Algerian Judo Competition Modality and its Impacts on Upper and Lower Limbs Strength Perseverance and Limitations. Orthopedics and Sports Medicine: Open Access Journal, 3(4), 293-299. https://doi.org/10.32474/OSMOAJ.2020.03.000168

Belkadi, A., Beboucha, W., Benhammou, S., Moussa, M., Bouzoualegh, M., & Dairi, A. (2025). Effects of concurrent in-season training on physiological functions required for top handball performance athletes. Scientific Journal of Sport and Performance, 4(1), 40-54. https://doi.org/10.55860/JIXW8099

Belkadi, A., Othman, B., Mohamed, S., M, B. H., Gleyse, J., Adel, B., … Gleyse, J. (2015). Contribution to the Identification of the Professional Skills Profile of Coaches in the Algerian Sport Judo System. International Journal of Sports Science, 5(4), 145-150.

Benchehida, A., Belkadi, A., Zenati, Y., Benbernou, O., Cherara, L., & Sebbane, M. (2021). Implementation of An Adapted Physical Activity Therapy Protocol for Patients with Low Back Pain. Gymnasium, 22(1), 83-96. https://doi.org/10.29081/gsjesh.2021.22.1.06

Benhammou, S., Mourot, L., Clemente, F. M., Coquart, J., & Belkadi, A. (2024). Is test specificity the issue in assessing aerobic fitness and performance of runners? A systematic review. The Journal of Sports Medicine and Physical Fitness, 64(6), 539-549. https://doi.org/10.23736/S0022-4707.23.15619-2

Benhammou, S., Mourot, L., Coquart, J., Belkadi, A., Mokkedes, M. I., & Bengoua, A. (2022). The 180/20 intermittent athletic test : A new intermittent track test to assess the maximal aerobic speed in middle-distance runners. Revista andaluza de medicina del deporte, 15(1), 6-11. https://doi.org/10.33155/j.ramd.2021.08.001

Borresen, J., & Lambert, M. I. (2008). Autonomic control of heart rate during and after exercise. Sports medicine, 38(8), 633-646. https://doi.org/10.2165/00007256-200838080-00002

Boudehri, M. E. amine, Belkadi, A., Dahoune, O., & Atallah, A. (2023). The effects of circuit exercise training strategy on health-related physical fitness level and biomarkers in elderly people with cardiovascular diseases. Quality in Sport, 11(1), 16-31. https://doi.org/10.12775/QS.2023.11.01.002

Buchheit, M., Simon, C., Piquard, F., Ehrhart, J., & Brandenberger, G. (2004). Effects of increased training load on vagal-related indexes of heart rate variability : A novel sleep approach. American Journal of Physiology-Heart and Circulatory Physiology, 287(6), H2813-H2818. https://doi.org/10.1152/ajpheart.00490.2004

Cannon, C. P., Battler, A., Brindis, R. G., Cox, J. L., Ellis, S. G., Every, N. R., … Simoons, M. L. (2001). American College of Cardiology key data elements and definitions for measuring the clinical management and outcomes of patients with acute coronary syndromes : A report of the American College of Cardiology . Journal of the American College of Cardiology, 38(7), 2114-2130.

Cherara, L., Belkadi, A., Mesaliti, L., & Beboucha, W. (2022). Characteristics of Handgrip (Kumi-Kata) Profile of Georgian Elite Judo Athletes. Gymnasium, 23(1), 54-66. https://doi.org/10.29081/gsjesh.2022.23.1.04

Cornelissen, V. A., Verheyden, B., Aubert, A. E., & Fagard, R. H. (2010). Effects of aerobic training intensity on resting, exercise and post-exercise blood pressure, heart rate and heart-rate variability. Journal of human hypertension, 24(3), 175-182. https://doi.org/10.1038/jhh.2009.51

Del Rosso, S., Nakamura, F. Y., & Boullosa, D. A. (2017). Heart rate recovery after aerobic and anaerobic tests : Is there an influence of anaerobic speed reserve? Journal of Sports Sciences, 35(9), 820-827. https://doi.org/10.1080/02640414.2016.1166391

Deus, L. A., Sousa, C. V., Rosa, T. S., Souto Filho, J. M., Santos, P. A., Barbosa, L. D., … Simões, H. G. (2019). Heart rate variability in middle-aged sprint and endurance athletes. Physiology & behavior, 205, 39-43. https://doi.org/10.1016/j.physbeh.2018.10.018

Draghici, A. E., & Taylor, J. A. (2016). The physiological basis and measurement of heart rate variability in humans. Journal of Physiological Anthropology, 35, 22. https://doi.org/10.1186/s40101-016-0113-7

Freeman, J. V., Dewey, F. E., Hadley, D. M., Myers, J., & Froelicher, V. F. (2006). Autonomic nervous system interaction with the cardiovascular system during exercise. Progress in cardiovascular diseases, 48(5), 342-362. https://doi.org/10.1016/j.pcad.2005.11.003

Fu, Q. I., & Levine, B. D. (2013). Exercise and the autonomic nervous system. Handbook of clinical neurology, 117, 147-160. https://doi.org/10.1016/B978-0-444-53491-0.00013-4

Gamelin, F.-X., Baquet, G., Berthoin, S., Thevenet, D., Nourry, C., Nottin, S., & Bosquet, L. (2009). Effect of high intensity intermittent training on heart rate variability in prepubescent children. European journal of applied physiology, 105(5), 731-738. https://doi.org/10.1007/s00421-008-0955-8

Hautala, A. J., Kiviniemi, A. M., & Tulppo, M. P. (2009). Individual responses to aerobic exercise : The role of the autonomic nervous system. Neuroscience & Biobehavioral Reviews, 33(2), 107-115. https://doi.org/10.1016/j.neubiorev.2008.04.009

Hautala, A. J., Makikallio, T. H., Kiviniemi, A., Laukkanen, R. T., Nissila, S., Huikuri, H. V., & Tulppo, M. P. (2003). Cardiovascular autonomic function correlates with the response to aerobic training in healthy sedentary subjects. American Journal of Physiology-Heart and Circulatory Physiology, 285(4), H1747-H1752. https://doi.org/10.1152/ajpheart.00202.2003

Hinojosa-Laborde, C., Chapa, I., Lange, D., & Haywood, J. R. (1999). Gender differences in sympathetic nervous system regulation. Clinical and Experimental Pharmacology and Physiology, 26(2), 122-126. https://doi.org/10.1046/j.1440-1681.1999.02995.x

Iellamo, F., Volterrani, M., Di Gianfrancesco, A., Fossati, C., & Casasco, M. (2018). The Effect of Exercise Training on Autonomic Cardiovascular Regulation : From Cardiac Patients to Athletes. Current Sports Medicine Reports, 17(12), 473-479. https://doi.org/10.1249/JSR.0000000000000544

Joyner, M. J., Charkoudian, N., & Wallin, B. G. (2008). A sympathetic view of the sympathetic nervous system and human blood pressure regulation. Experimental physiology, 93(6), 715-724. https://doi.org/10.1113/expphysiol.2007.039545

Jurca, R., Church, T. S., Morss, G. M., Jordan, A. N., & Earnest, C. P. (2004). Eight weeks of moderate-intensity exercise training increases heart rate variability in sedentary postmenopausal women. American heart journal, 147(5), e8-e15. https://doi.org/10.1016/j.ahj.2003.10.024

Kraama, L., Yague, P., Kyröläinen, H., Pulkkinen, S., Matinsalo, T. & Linnamo, V. Effects of eight weeks of physical training on physical performance and heart rate variability in children. Biomedical Human Kinetics, 2017, Sciendo, vol. 9 no. 1, pp. 175-180. https://doi.org/10.1515/bhk-2017-0024

Kuss, O., Schumann, B., Kluttig, A., Greiser, K. H., & Haerting, J. (2008). Time domain parameters can be estimated with less statistical error than frequency domain parameters in the analysis of heart rate variability. Journal of electrocardiology, 41(4), 287-291. https://doi.org/10.1016/j.jelectrocard.2008.02.014

Ladawan, S., Klarod, K., Philippe, M., Menz, V., Versen, I., Gatterer, H., & Burtscher, M. (2017). Effect of Qigong exercise on cognitive function, blood pressure and cardiorespiratory fitness in healthy middle-aged subjects. Complementary Therapies in Medicine, 33, 39-45. https://doi.org/10.1016/j.ctim.2017.05.005

Lehrer, P. M., & Gevirtz, R. (2014). Heart rate variability biofeedback : How and why does it work? Frontiers in psychology, 5, 756. https://doi.org/10.3389/fpsyg.2014.00756

Levy, W. C., Cerqueira, M. D., Harp, G. D., Johannessen, K.-A., Abrass, I. B., Schwartz, R. S., & Stratton, J. R. (1998). Effect of endurance exercise training on heart rate variability at rest in healthy young and older men. The American journal of cardiology, 82(10), 1236-1241. https://doi.org/10.1016/S0002-9149(98)00611-0

Makivić, B., Nikić Djordjević, M., & Willis, M. S. (2013). Heart Rate Variability (HRV) as a tool for diagnostic and monitoring performance in sport and physical activities. Journal of Exercise Physiology Online, 16(3).

Manar, B., Adel, B., Lalia, C., & Saddak, B. (2023). Investigating the Impact of Physiological and Neuromuscular Performance in Highly Trained Judo Athletes of Different Weight Categories. Slobozhanskyi Herald of Science and Sport, 27(3), 118-127. https://doi.org/10.15391/snsv.2023-3.002

Mandigout, S., Melin, A., Fauchier, L., N'Guyen, L. D., Courteix, D., & Obert, P. (2002). Physical training increases heart rate variability in healthy prepubertal children. European journal of clinical investigation, 32(7), 479-487. https://doi.org/10.1046/j.1365-2362.2002.01017.x

Oliveira, R. S., Barker, A. R., Wilkinson, K. M., Abbott, R. A., & Williams, C. A. (2017). Is cardiac autonomic function associated with cardiorespiratory fitness and physical activity in children and adolescents ? A systematic review of cross-sectional studies. International journal of cardiology, 236, 113-122. https://doi.org/10.1016/j.ijcard.2017.02.022

Rocchetti, M., Malfatto, G., Lombardi, F., & Zaza, A. (2000). Role of the input/output relation of sinoatrial myocytes in cholinergic modulation of heart rate variability. Journal of cardiovascular electrophysiology, 11(5), 522-530. https://doi.org/10.1111/j.1540-8167.2000.tb00005.x

Romanchuk, A., & Dolgier, E. (2017). Effects of long-term training experience of aerobic exercises on middle-aged women. Journal of Physical Education and Sport (JPES), 17(2), Art 102, pp. 680-687. https://doi.org/10.7752/jpes.2017.02102

Rongzhou, W. (2011). Heart rate variability analysis of 750 healthy children. Journal of Clinical Pediatrics, 29(7), 642-644.

Rowe, J. W., & Troen, B. R. (1980). Sympathetic nervous system and aging in man. Endocrine Reviews, 1(2), 167-179. https://doi.org/10.1210/edrv-1-2-167

Sacknoff, D. M., Gleim, G. W., Stachenfeld, N., & Coplan, N. L. (1994). Effect of athletic training on heart rate variability. American heart journal, 127(5), 1275-1278. https://doi.org/10.1016/0002-8703(94)90046-9

Saddek, B., Coquart, J. B. J., Mourot, L., Adel, B., Idriss, M. M., Ali, B., & Djamel, M. (2020). Comparison of Two Tests to Determine the Maximal Aerobic Speed. Acta Facultatis Educationis Physicae Universitatis Comenianae, 60(2), 241-251. https://doi.org/10.2478/afepuc-2020-0020

Sandercock, G. R., Bromley, P. D., & Brodie, D. A. (2005). Effects of exercise on heart rate variability : Inferences from meta-analysis. Medicine and science in sports and exercise, 37(3), 433-439. https://doi.org/10.1249/01.MSS.0000155388.39002.9D

Scheer, K. S., Siebrant, S. M., Brown, G. A., Shaw, B. S., & Shaw, I. (2014). Wii, Kinect, and Move. Heart rate, oxygen consumption, energy expenditure, and ventilation due to different physically active video game systems in college students. International journal of exercise science, 7(1), 22. https://doi.org/10.70252/XHTR7649

Selig, S. E., Carey, M. F., Menzies, D. G., Patterson, J., Geerling, R. H., Williams, A. D., … Hare, D. L. (2004). Moderate-intensity resistance exercise training in patients with chronic heart failure improves strength, endurance, heart rate variability, and forearm blood flow. Journal of cardiac failure, 10(1), 21-30. https://doi.org/10.1016/S1071-9164(03)00583-9

Selvaraj, N., Jaryal, A., Santhosh, J., Deepak, K. K., & Anand, S. (2008). Assessment of heart rate variability derived from finger-tip photoplethysmography as compared to electrocardiography. Journal of medical engineering & technology, 32(6), 479-484. https://doi.org/10.1080/03091900701781317

Senouci, A., Asli, H., Belkadi, A., Bouhella, H., & Koutchouk, S. M. (2024). The Effect of Cold Therapy on Delayed Onset Muscle Soreness and Quadriceps Femoris Strength After High-Intensity Eccentric Training. Gymnasium, 25(2), 34-50.

Shaffer, F., & Ginsberg, J. P. (2017). An overview of heart rate variability metrics and norms. Frontiers in public health, 5, 258. https://doi.org/10.3389/fpubh.2017.00258

Sharma, V. K., Subramanian, S. K., Arunachalam, V., & Rajendran, R. (2015). Heart Rate Variability in Adolescents - Normative Data Stratified by Sex and Physical Activity. Journal of Clinical and Diagnostic Research : JCDR, 9(10), CC08-CC13. https://doi.org/10.7860/JCDR/2015/15373.6662

Sztajzel, J. (2004). Heart rate variability : A noninvasive electrocardiographic method to measure the autonomic nervous system. Swiss medical weekly, 134(35-36), 514-522.

Tang, Y.-Y., Ma, Y., Fan, Y., Feng, H., Wang, J., Feng, S., … Li, J. (2009). Central and autonomic nervous system interaction is altered by short-term meditation. Proceedings of the national Academy of Sciences, 106(22), 8865-8870. https://doi.org/10.1073/pnas.0904031106

Thayer, J. F., Hansen, A. L., Saus-Rose, E., & Johnsen, B. H. (2009). Heart rate variability, prefrontal neural function, and cognitive performance : The neurovisceral integration perspective on self-regulation, adaptation, and health. Annals of Behavioral Medicine, 37(2), 141-153. https://doi.org/10.1007/s12160-009-9101-z

Ueno, L. M., & Moritani, T. (2003). Effects of long-term exercise training on cardiac autonomic nervous activities and baroreflex sensitivity. European journal of applied physiology, 89(2), 109-114. https://doi.org/10.1007/s00421-002-0777-z

Vanderlei, L. C. M., Silva, R. A., Pastre, C. M., Azevedo, F. M. de, & Godoy, M. F. (2008). Comparison of the Polar S810i monitor and the ECG for the analysis of heart rate variability in the time and frequency domains. Brazilian Journal of Medical and Biological Research, 41, 854-859. https://doi.org/10.1590/S0100-879X2008005000039

Vigo, D. E., Siri, L. N., & Cardinali, D. P. (2019). Heart Rate Variability : A Tool to Explore Autonomic Nervous System Activity in Health and Disease. In P. Á. Gargiulo & H. L. Mesones Arroyo (Éds.), Psychiatry and Neuroscience Update : From Translational Research to a Humanistic Approach-Volume III (p. 113-126). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-95360-1_10

Wheat, A. L., & Larkin, K. T. (2010). Biofeedback of heart rate variability and related physiology : A critical review. Applied psychophysiology and biofeedback, 35(3), 229-242. https://doi.org/10.1007/s10484-010-9133-y

Yacine, Z., Othmane, B., Adel, B., Mohamed, S., Aabdelkader, B., & Lalia, C. (2020). Functional movement screening as a predictor of injury in highly trained female's martial arts athletes. Polish Hyperbaric Research, 71(2), 67-74. https://doi.org/10.2478/phr-2020-0012

Yan, W., Jun, X., & Guo-Rong, G. (2006). An analysis of heart rate variability in patients with coronary heart disease. Medical Journal of Qilu, 01.

Yeh, C.-H., & Kuo, Y.-C. (2012). Wii Sports.

Zhou, X., Zhou, L., Wang, S., Yu, L., Wang, Z., Huang, B., … Jiang, H. (2016). The use of noninvasive vagal nerve stimulation to inhibit sympathetically induced sinus node acceleration : A potential therapeutic approach for inappropriate sinus tachycardia. Journal of cardiovascular electrophysiology, 27(2), 217-223. https://doi.org/10.1111/jce.12859

SUSTAINABILITY & SPORTS SCIENCE JOURNAL

ORIGINAL ARTICLE

Forest Green Rovers Football Club: A model for tomorrow's golf clubs

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ABSTRACT

Apparently golf and the ecological transition are hardly compatible. However, golf's governing boards (national and international) are fully aware of the need to take this imperative into account. In the field, it is up to golf directors to rise to the challenge. In practical terms, the question is: how can we, at an operational level, combine the offer of golf with the ecological transition in the long term? This central question also constitutes our problem. Our hypothesis is that a pioneering football club in this area, Forest Green Rovers Football Club, could provide an operational model that could help them. Our research methodology is therefore based on the four-stage approach proposed by Berger Douce and Nguyen Tan. This leads us to propose two operational models that can help golf managers implement the ecological transition in their clubs.

Keywords: Environment, Sustainability, Golf, Ecological transition, Golf course managers, Operational models.

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INTRODUCTION

"*Faced with the consequences of global change, growing pressure on resources and increasing environmental regulations, all stakeholders in the industry must realise that to safeguard its activities and the attractiveness of the game of golf, it is imperative to initiate an ecological transition plan of unprecedented ambition*" (Golf Course 2030). Far from the image perceived by many distant observers, golf's governing bodies are now fully aware of the need to implement the ecological transition on all golf courses. Many initiatives are already underway at various levels (public authorities, federations, clubs, partners, etc.). The priority now is to get things up and running. The question is how do we go about it? The answer, however, is not simple. Although there are several possible approaches, we prefer to define the task at hand by using a model already in place within a different discipline. Our hypothesis is as follows. Forest Green Rovers Football Club's (FGRFC) eco-responsible sporting perspective could be used as an operational model for the ecological transition of the golf clubs of tomorrow. To examine this, we have chosen to proceed in four stages. After presenting the current thinking on the subject (1), we will indicate our question (2) then our methodology (3) and finally the results obtained: the Ambition+ and Adaptation models (4).

GOLF AND THE ECOLOGICAL TRANSITION

Awareness

The early 1960s

At that time, the notions of sustainable development, social and environmental responsibility and sustainability were not major concerns. Quite the contrary, in fact. In 1964, G. C. Nutter, editor-in-chief of one of the most prestigious journals for American golf superintendents (The Golf Course Reporter) condemned Rachel Carson's book (Silent Spring, 1962), in which she criticised entrepreneurs who used chemicals that were damaging to the environment, particularly in the golf industry. Carson even suggested limiting the use of some of them (biocides), which at the time seemed absolutely essential for maintaining golf courses (Millington and Wilson, 2016).

Early 2000s

Another article published in the same journal (Ostmeyer, 2001) defends a radically different position and encourages greenkeepers to become aware of the problem.

Over the last 40 years, our perception of this issue has changed profoundly. Social and environmental responsibility (SER) has become an important issue in the world of golf, particularly in terms of the social value that golf brings to the environment (Hammond and Hudson, 2007; Golf Business International, 2021). As with other companies operating in the sports and leisure sector (Ratten and Babiak, 2010; Ratten, 2010), people involved in the world of golf are now seeking to integrate SER principles into their operations.

Few contributions address this issue at club level, even though many philanthropic initiatives have long existed in this sector (International Golf Federation, 2021): charitable fundraising, aid to surrounding communities, financial support, etc. At environmental level, there is currently a focus on five key issues (White, 2021): water, decarbonisation, pesticides, biodiversity and multifunctionality. There is a good reason for this: maintaining a golf course requires a large quantity of resources, the use of which must now be part of an eco-responsible approach (Scott and al., 2018). Here is a brief overview of these key issues.

Water. The stakes are high, both economically and politically (Cohen and al., 1999; Balogh and Walker, 2020; Shaddox, and al., 2022). Today, the aim is to limit consumption, rationalise its use and recycle used

water as often as possible. The choice of grasses planted (which consume more or less water) can also be crucial in certain regions (McCarty, 2018).

Decarbonisation. Maintaining a golf course requires numerous mechanical operations that are sources of carbon emissions (Tidåker and al., 2017): repeated grass-cutting, fertilisation, aeration, sanding, energy consumption by buildings located on the site, etc. In this sector, limiting the carbon footprint, therefore, means: improving course maintenance conditions, limiting the use of nitrogen fertiliser, recycling grass cuttings, investing in electric equipment, etc.

Pesticides. For many years, greenkeepers have been using them to guarantee the *"playability*" and verdant aspect of their courses. In the United States, since the publication of the book The greening of golf: Sport, globalization and the environment (2016), more responsible practices have been introduced: less systematic use, choice of less toxic products, even voluntary total elimination in some cases.

Biodiversity. The golf course has many strengths in this area. The challenge is to preserve and develop them (Tanner and Gange, 2005; Colding and Folke, 2009; Petrosillo and al., 2019). One effective way of doing this is to preserve biodiversity and the naturalisation of areas where the game is not played by using native vegetation, particularly near water hazards.

Multifunctionality. Although it seems less essential, multifunctionality is one way that could enable golf courses to offer services not exclusively to its members (Dahl Jensen and al., 2017). As at St Andrews (Boden, 2015), providing access to non-golfers under certain conditions, opening clubhouses to other publics, implementing educational programmes, etc. could be interesting options to develop.

The issue of the social and environmental responsibility of golf clubs is multifaceted and today concerns four main groups of actors: players (amateurs and professionals), managers (directors and greenkeepers), sporting authorities (federations and leagues) and public institutions (States, local government).

In France, the public authorities see the consideration of SER issues by sports organisations as part of a wider process (Bayle, 2012; François and Boucher, 2023) aimed at meeting national and international commitments. This is mainly reflected in changes to certain legislation concerning, for example, the use of chemicals. For federations, this is now a major issue, as it affects both the conditions in which sports are practised and the image of the activity. In France, it has led the French Golf Federation (FGF) to appoint a vice-president (Sylvianne Villaudière) to lead a strategic committee on ecological transition.

For managers of golf courses, the issue is more complex. They have to reconcile economic imperatives (profitability of the facilities), golfers' expectations (quality of the course), the general public's perception (often negative) and regulatory changes (concerning watering, for example).

At these different levels, a number of discussions are currently underway[1].

Current thinking

In many countries, sustainable development has been a major issue in public sports policy since the early 2000s (Zedet, 2006). Sport concerns all three pillars of sustainable development (social, economic and environmental). It is therefore at the crossroads of the majority of related issues. In France, these discussions

[1] In what follows, we will focus on the perceptions of sports users.

have led to a sustainable development strategy for sport since 2011 (SDSS). In the European model of sport, the sports federations are the logical relays for the priorities defined. To achieve this, three tools are currently favoured (Bayle and al., 2011): information, raising awareness of ecological practices and the development of new marketing tools.

The French Golf Federation (FGF) is emerging as a leading sports federation in terms of eco-responsibility. Its action plan also focuses on three areas (FGF, 2022):

- The updating of maintenance methods, with, in particular, following the Labbé law[2], the elimination of the use of synthetic physio-sanitary products by 2025,
- Rational management of water resources: renovation of irrigation systems, watering strictly limited to playing areas, rainwater harvesting, use of recycled water,
- Preserving biodiversity on the courses by protecting existing flora and fauna.

Although it is the federations that provide the initiative (Royal and Ancient, 2018), only the stakeholders and therefore the clubs, have the power to actually implement the proposed action plans. To date, most of the work (François and Bayle, 2014) on this issue has focused on professional clubs, and with this in mind, several results stand out (see p. 12). One of these is a certain difficulty in operationalising the announced ambitions, despite relatively significant resources.

This issue is even more acute for amateur clubs, whose resources are limited. As a direct result of the specificities surrounding these types of clubs a series of questions naturally arise for golf course managers around the running of the clubs.

What can be done? At what level and according to what priorities? How can we overcome the resistance of our members and customers? How do we deal with practical problems? These are some of the dilemmas facing the directors of amateur sports clubs. In golf, the managers are on the front line.

The question of implementation

There is a huge amount of work to be done on the ground (Bizzari, 2006; Mercatanti, 2017). Where would be the best place to start? Is it by limiting or even stopping the use of chemicals to maintain certain playing surfaces? Reducing water consumption or changing water provisioning conditions? Limiting mechanical operations? Encouraging the development of local biodiversity? Educating employees in these new practices? By doing everything possible to obtain environmental certification? Integrating the Corporate Social Responsibility (CSR) dimension into marketing initiatives? Or simply opt for (more) "*rustic*" golf courses?

Although some of these actions can undoubtedly be undertaken simultaneously, another difficulty faced by golf's managers is known as the "*Augusta Syndrome*" (Wheeler and Nauright, 2006; Millington and Wilson, 2017). This "*syndrome*" is the result of the increasing media coverage of golf on television, mainly "*Grand Slam*" events and, therefore, the Augusta Masters. With the broadcasting of this tournament and others that take place on particularly well-maintained courses with impeccable aesthetics, and therefore always verdant, many golfers, particularly wealthy ones, want to play in comparable conditions, which more often than not runs counter to the implementation of the CSR principles (Hammond and Hudson, 2007).

[2] Labbé Law. https://www.pan-europe.info/blog/labb%C3%A9-law-colloquium-%E2%80%93-assessment-and-prospects-towards-zero-pesticides-non-agricultural-areas

More generally, taking into account the opinions of customer-golfers on these issues cannot be neglected. The current literature (Minoli, 2018) underlines this. Many golfers pay little attention to these issues for two reasons: a lack of knowledge or even understanding of environmental issues and an unwillingness to bear the cost of the necessary investments via an increase in the price of green fees. More specifically, Fouillouze and al. (2023) distinguish four categories of golfer: the "*opposed*", who are not in favour of implementing eco-responsible management; the "*neutrals*", who are undecided; the "*supporters*", who are in favour of implementing pro-active management on CSR issues; and the "*committed*", who, by virtue of a close connection to nature, already incorporate eco-responsible principles into their behaviour on the course.

Another of their conclusions (Fouillouze and al.) relates to the need for subsidiarity. It will be difficult to make the ecological transition without the consent of the customer-golfers, at the risk of them moving away from the sport to the detriment of the clubs' economic health. It is also unthinkable that the transition will take place if the clubs are not the main vectors for its implementation.

The solution lies with the clubs

As Table 1 (Bouvet, 2009) shows, various categories of courses, and therefore clubs, can be distinguished on the basis of their preferred customers, their management methods or their environment.

Table 1. Three categorisations of golf courses.

Distinctive criteria	Types of courses	Definition
Preferred type of customers	Short golf courses	Courses with a reduced number of holes of fairly short distances, allowing beginners to learn and others to practise.
	With members	Courses located close to a large conurbation, which provides most of its members.
	For tourists	Courses in tourist areas for visiting players.
Style of management	For members only	Courses reserved exclusively for members.
	Private	Courses managed by a private association.
	Public	Courses managed by a local authority.
Environment	Links	Seaside courses, usually located in dunes, considered to be the `birthplace` of golf.
	Parkland	Courses in the countryside, forest or mountains.
	Real estate	Courses surrounded by residential areas.

Depending on their characteristics, the question of ecological transition is posed differently for these clubs.

Because of their smaller size and their primary purpose, short courses are easier to maintain and less subject to customer demands. In theory, they are well placed to fulfil the requirements of the ecological transition. Local courses, also known as member courses, derive most of their resources from membership fees. The challenge for them is therefore to try to include them in the discussions and in the implementation of the proposed adaptations. Tourist courses depend mainly on green fees sold to visiting golfers. For them, the dilemma is as follows: how to satisfy the demands of local pressure groups anxious to preserve privileged sites and at the same time those of tourists likely to prefer other destinations if the quality of the offer does not match their expectations?

The distinction between clubs according to their management style reflects different budgetary constraints: very "*loose*" for the former, variable for the latter and strong for the latter. Members golf clubs are those for which the ecological transition seems to be the easiest to implement from an economic point of view, as the members of these clubs generally agree to bear the costs of improving their facilities. In private clubs, where

profitability is more uncertain, the ecological issue comes up against management imperatives head-on. The question of priorities is therefore crucial. In public courses, everything depends on the general orientations chosen by the public managers of the course.

Links courses, which are natural courses par excellence (some of them have no irrigation system, for example), have often incorporated these requirements for a long time. Parklands and real estate courses, on the other hand, are subject to numerous constraints that need to be examined on a case-by-case basis.

When asked about this issue, golf managers[3] say that they most often refer to environmental programmes (Minoli and Smith, 2011) and in France to the Golf for Biodiversity programme launched by the FGF (2022), which aims to improve knowledge of the ecological issues associated with golf courses and land (Roquinarc'h and al., 2019). This is not without its problems (Minoli, 2018) for several reasons:

- As we saw earlier, few golfers feel concerned by these issues and even fewer are involved,
- The conditions required to host national or international events are not always compatible with the requirements of the ecological transition,
- For some managers, the cost-benefit analysis of the measures to be put in place is not a strong argument in favour of their introduction,
- Others doubt their effectiveness,
- The interests of owners, managers, greenkeepers and members in this matter rarely converge,
- A lack of time and information is also often cited.

Many golf managers are looking for a solution that would enable them 1) to overcome the problems listed above, 2) to have a framework (model) that has proved its overall effectiveness, 3) to implement the main precepts of the ecological transition without this being to the detriment of the stakeholders. Finally, is there an existing solution already in place in another sport?

PROBLEMATIC, RESEARCH QUESTIONS AND HYPOTHESIS

Problematic

In most golf clubs, the manager is part of a complex local eco-system (see Figure 1).

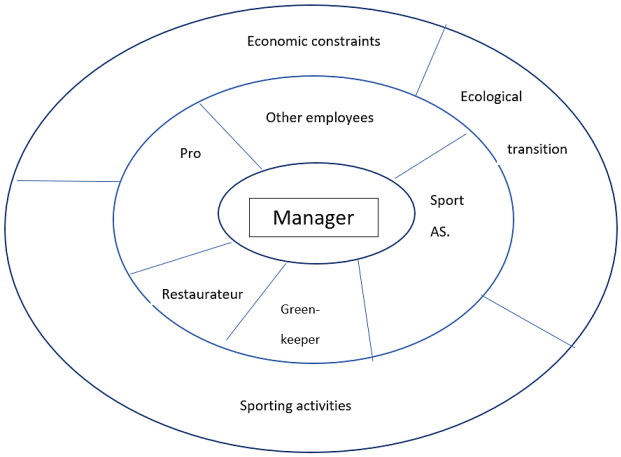

Figure 1. A golf manager's eco-system.

[3] We met the former managers of the Chalon sur Saône (public) and St Cloud ((private)) golf courses and the current managers of the Dijon Norges, Château d'Avoise (members), Gouverneur and Pont Royal (tourist) golf courses.

Today, the main role of the manager is to co-ordinate the activities of the staff in the first circle, taking into account the imperatives of the second. Depending on the status of the club, the sporting association is either the manager's employer or a major partner in defining the club's sporting policy. The greenkeeper can be seen as the manager's right-hand man, with whom he must work to offer members and visiting players the best possible golfing conditions based on the club's financial resources. As is the case for all company directors, the other employees (secretaries, gardeners, receptionists, starters, mechanics, etc.) are the human resources on which he must rely by adopting an appropriate management style. The restaurant manager may also be an employee of the club or run his own establishment. The majority of golfers are sensitive to the catering offer, and the caterer is often one of the club's key partners. Finally, the pro(s) are the teachers who are responsible for introducing beginners to the game and for giving lessons to more experienced players. They play a vital role in "*creating new golfers*" and maintaining the loyalty of senior players.

Beyond the differences that may exist between the members of the association and the director in relation to the Augusta Syndrome mentioned above. For example, the pros may wish to have the best possible working tool to attract a large clientele, the restaurant owners may be sensitive to the image and reputation of the club and the greenkeeper may have a personal point of view on the actions to be carried out on the course. Meeting all these expectations is not always easy, especially when the imperatives of the ecological transition need to be taken into account. So what should be done? A twofold necessity is emerging:

- Make choices, conditioned by local imperatives (type of site, irrigation system, existing flora and fauna, etc.) and time (weather, season, visitor numbers, etc.),
- Be based on a reference framework that enables it to justify its actions to all stakeholders and to implement an overall action plan.

In other words, the problem it faces, and which we will address in this contribution, is as follows.

At an operational level, how can we sustainably reconcile sporting activities and ecological transition?
The operational level is that of implementation in the clubs. The sustainable nature of the actions undertaken refers to the obligation to make choices that do not jeopardise the club's long-term future, and therefore to take into account the economic constraints associated with its management style. Services correspond to access to the course and associated facilities (driving range, putting green, training area) and any associated services. The ecological transition is generally defined as: "*All the changes made to the economic and social model with the aim of meeting the requirements of sustainable development and reducing society's ecological footprint*" (Makowiak, 2023).

According to the directors interviewed, there are three different ways of doing this:

- Try to apply directly the recommendations made by the governing bodies,
- Draw inspiration from practices implemented by other companies of comparable size operating in other sectors,
- Draw on "*models*" from the sporting world, in particular (professional) sports clubs,
- In order to proceed further, it is necessary to examine these three scenarios in more detail.

Three ways of initiating action
To implement the ecological transition, a golf manager's first instinct is to turn to his or her umbrella federation. In its action plan (FGF, 2022a), the FGF offers training courses to help managers commit their structure to preserving biodiversity and practising ecologically responsible golf. The "*Keys to making the ecological*

transition at my golf course" programme is the one most directly aimed at golf managers. It comprises four main parts:

- The constraints and opportunities associated with sustainable development issues for golf,
- The challenges of the ecological transition,
- The environmental action plan for a golf course,
- Promoting its commitments to players and staff (FGF, 2022c).

There is no doubt that this is a training programme that could prove extremely useful, but for reasons we will come-back to below, it has not yet been very successful[4], which suggests that other, more global and easily transferable solutions should be examined.

Most golf clubs are profit centres. Another possibility mentioned by the golf directors we met was to find inspiration in what is being done in small and medium-sized enterprises (SMEs). A large number of SMEs wishing to implement a green transition plan rely on the environmental programmes available to them (Darnall and Sides, 2010). The aim of these general programmes is to encourage smaller businesses to use their resources more efficiently, reduce waste and obtain certification (ISO 2015, for example). These programmes can be more or less formalised (McKeiver and Gadenne, 2005) and therefore not always easy to apply. In the golf sector, they are often difficult to implement for the following reasons (Minoli, 2018):

- Little external incentive, as owners, members and, even more so, visiting players have no short-term interest,
- A poor perception of the additional benefits that could result, as golf courses are seen by some, by their very nature, as structures that already do more for the environment than others,
- A lack of financial resources.

Another oft-repeated difficulty is the need to satisfy the requirements of multiple stakeholders with often divergent expectations and demands. However, as the business model of (professional) sports clubs is more similar to that of golf clubs, it is, in the eyes of golf managers, another possible source of benchmarking. Research on this issue focuses mainly on professional clubs (François and Bayle, 2014). These are similar to golf clubs in several respects:

- There are many different stakeholders (owners, managers, fans, sponsors, public authorities, media),
- With the exception of the wealthiest of them, economic constraints are strong,
- Environmental issues have only recently been taken into account,
- The supply is taking place within a framework that is already highly regulated,
- There are many uncertainties that can affect the way in which the activity is carried out.

What do these studies show? Three things in particular:

- The CSR practices of French professional football clubs are most often "*cosmetic*",
- The adoption of these practices is generally the result of external pressure, and
- Legitimacy appears to be the primary motivation.

On the basis of these results, it would appear that professional sports clubs can hardly be taken as a model, unless a club can be found whose environmental commitment is neither cosmetic, nor a response to institutional pressure, nor the result of a search for legitimacy. To our knowledge, only one club satisfies all

[4] In 2022, only 44 people, including managers and greenkeepers, had taken this programme.

three of these conditions, while at the same time having to deal with constraints specific to the sporting sector: Forest Green Rovers Football Club.

Research hypothesis

On the basis of the above, our research hypothesis is as follows: Forest Green Rovers Football Club can provide an operational model for golf clubs (and therefore their managers). This hypothesis is based on the following seven observations:

- The findings set out above, namely:
  - The need to satisfy stakeholders with different and conflicting requirements,
  - For the majority of clubs, the existence of a strong economic constraint,
  - The limited time available for training courses on this subject,
- The risk of settling for cosmetic measures,
- The wish expressed by the directors to have a simple, global and effective reference framework to initiate and coordinate their actions,
- The hindsight that can now be gained from this model, which has been in place for several years,
- The communication advantages associated with this choice, and even the opportunities for diversification (in the strategic sense of the term) that go with it,
- FGRFC owner Dale Vince's desire to set an example: "*There are two kinds of changes you can make in the world, the one you can make yourself, which is necessarily limited, and the second is to be a catalyst. Showing people what can be done and generating change that way, and that's the one we prefer to do*[5]",
- The effectiveness of this business model, which has not only already proved its worth, but has also already set an example for clubs such as Bétis Séville in Spain, Lille Olympique Sporting Club in France and other football clubs in South America,
- Lastly, as Table 2 shows, the proximity of the priority actions identified in the two categories of club.

Table 2. Priority actions identified by the FGRFC and golf clubs.

Related actions to:	**FGRFC**	**Golf clubs**
Equipment management	Use of organic products	Limiting and then gradually banning physio-sanitary products
Reticence of the public	Club fans	Club members
Adapting infrastructures	Use of solar panels	Preserving existing biodiversity
Water management	Use of spectator urine and rainwater	Limit consumption and recycle as much as possible
The use of electric vehicles	For club members and spectators	For maintenance vehicles
Using recycled materials	Shirts, small equipment	Goodies, course accessories, small equipment
The type of catering	Bar	Club house
Sporting performances	Team one results	Club quality and image
Limiting the carbon footprint	Thanks to changes in maintenance conditions with a view to securing "*carbon neutral*" certification	Thanks to changes in maintenance conditions and the renewal of maintenance equipment
Choice of partners	Sponsors and suppliers	Sponsors and suppliers

However, comparison is not reason enough! This is why, after briefly presenting the FGRFC (2.4.), we will then have to choose an approach that will enable us to transfer the key concepts identified in the FGRFC model to golf clubs.

[5] https://www.fgr.co.uk/another-way

Forest Green Rover Football Club

Founded in 1889 as Nailsworth and Forest Green Rovers, FGRFC is based in Nailsworth (Great Britain). Until 2010, when the current chairman, Dale Vince, who is also chairman of Ecotricity, took over, the club played in the regional divisions. Vince's ambition was to make it the first "*environmentally responsible*" club. After several unsuccessful attempts, at the end of the 2016/2017 season, the club was promoted to the fourth regional division (League Two) and the town of Nailsworth became the smallest town in history to host an English professional club. In 2022, the club moved up to the third division (League One), where it failed to hold its own.

Aside from its sporting achievements, what sets the club apart is its "*green*" positioning, a title that FIFA recognised in 2017 when it named it the "*greenest club in the world*". This approach is based on five main pillars:

Energy. Solar panels provide 20% of total energy consumption, with the remainder supplied by the owner's company, Ecotricity, which specialises in 100% renewable electricity and carbon-neutral gas.

Carbon footprint. The club has made a commitment to the United Nations to reduce its emissions by 50% by 2030. Several levers are being used to achieve this:

- Reducing water consumption,
- The use of electric vehicles for maintenance and player transport,
- Installing recharging points in spectator car parks and encouraging spectators to use public transport,
- Extensive use of teleworking for club employees,
- Organising group travel for supporters.

Food. The club is vegan. It has also signed partnerships aimed at limiting plastic waste and using refillable or recyclable products.

The stadium. The field captures rainwater and recycles it for irrigation. No chemicals or pesticides are used. The Eco Park enclosure is made almost exclusively of wood. The site contains 500 trees and 1.8 kilometres of hedges to encourage biodiversity. It is located in an area that is easily accessible by public transport.

Communications. As the club's position is now known and recognised throughout the world[6], it is keen to spread its model and regularly presents its actions to outsiders. (Sources: club website and Papp-Vary and Farkas, 2022).

In its 2018 business report, it said, "*Forest Green Rovers (FGR) aims to become a truly sustainable football club, a world first. Our aim is to make it a place where an eco-responsible approach can be presented to a new audience, football fans. Indeed, we believe that we have the opportunity to introduce sustainability into the world of sport in the broadest sense, and not just football. Beyond its core business, FGRFC is an eco-system where production and consumption are thought through from an ecological and social sustainability perspective*" (Forest Green Rovers, 2018). The club strives to take these principles into account in all aspects of its business, but also to ensure that the beliefs and behaviours of consumers who come to watch matches change (FGR Environment Report, 2017).

The club aims to be a model, not only for other football clubs, but also for other sports clubs. By adopting an appropriate scientific approach, we think this is perfectly conceivable for golf clubs.

[6] The club obtained the ISO 1400 international environmental standard in 2018.

METHODOLOGY

How can operational principles be transferred from one domain to another?

According to Kourilsky (1990), the origin of knowledge shared between several disciplines is to be found in "*unifying concepts*", i.e. general principles (emergence, organisation, etc.), "*common frameworks*" adopted as objects of study by certain disciplines. For example, the law of exponential growth, which has been verified for both bacterial populations and telephone communications, is a good example of a "*law*" shared by several disciplines. From this point of view, a model born in one discipline and later used in another must be preceded by an analysis of a double compatibility: a horizontal compatibility and a vertical compatibility. Horizontal compatibility refers to the need to define processes, functions, factors and a common language between disciplines. The second is more fundamental. It consists of verifying the validity of the orders or the underlying logic levels. For example, a technical process that works at a given level is not necessarily operational in a wider context. Similarly, in economics, certain results that are perfectly valid in microeconomics can lead to macroeconomic heresies. In the field of science, the choice of scale of analysis is a crucial factor. Following the recommendations made by Descartes in his Discourse on Method, another approach may be to "*divide*" a complex problem into a series of simpler problems. In some cases, this division into "*prime elements*" makes it possible to identify an "*elementary particle*", common to several fields, which can then be used to understand certain objects of study more easily. Darwin developed his theory of natural selection using concepts specific to horticulture and animal husbandry. The use of nomadic concepts does, however, need to be surrounded by important methodological precautions. When such analogies are used with care they can prove highly fruitful (Bouvet, 2009).

Berger-Douce and Durieux Nguyen Tan (2002) propose a method based on analogy and metaphor. We have chosen to use it because of its operational nature. This method comprises four stages.

The four stages of the approach proposed by Berger-Douce and Durieux Nguyen Tan

Stage 1. The purpose of the first stage is to "*clear the ground*", i.e. to present the problem by identifying the key concepts or components that will be used during the transfer. In this case, we need to determine the main axes around which the Forest Green Rovers model is based.

Stage 2. The second stage consists of using the general concepts identified in the previous stage to design a simplified "*source framework*" on which the analogy will be based. To do this, we need to present the choices made by the FGRFC in each of the directions identified.

Stage 3. The third stage consists of identifying the elements which play similar roles in similar areas. This phase is often referred to as the equivalence preparation phase'. In a way, it involves "*translating*" observations in the first domain into possible actions in the second.

Stage 4. The fourth stage is, strictly speaking, the transfer of knowledge from the original domain, football, to the target domain, golf. The aim is to infer from the elements identified in the previous stages applicable rules that will provide solutions to the problem encountered, in this case the operational implementation of the ecological transition in golf clubs.

Application

Stage 1. In view of the above, we believe that the FGRFC model has three main components:

- The economic axis, which determines production and supply choices,

- The environmental aspect, which determines the choices made in terms of construction, development and management of facilities,
- The social dimension, which aims to influence the behaviour of stakeholders.

Stage 2. On the basis of these three axes, the source framework is made up of the commitments made by the FGRFC at these three levels. These are as follows:
At economic level:

- Have a responsible purchasing policy,
- Involve sponsors in the chosen activities,
- Limiting the digital footprint,
- Give priority to sustainable food.

On an environmental level:

- Encourage sustainable mobility,
- Limit waste,
- Preserving the environment,
- Limiting water consumption.

On a societal level:

- Managing volunteers responsibly,
- Raising awareness internally,
- Educate the population about sustainable development,
- Seek to obtain "*labels*".

Stage 3. Applied to golf, these commitments lead to the following recommendations:
At the economic level:

- Have a responsible purchasing policy = for all infrastructures (clubhouse, restaurant, course, etc.) choose equipment (and therefore suppliers) compatible with the implementation of the ecological transition.
- Involving sponsors in environmentally-friendly practices = choosing as partners, particularly for club competitions, companies that care about the environment.
- Limit the digital footprint = keep computer equipment for a long time and limit the use of very high definition videos.
- Give priority to sustainable food = offer organic, animal welfare-friendly, seasonal products in the clubhouse restaurant, limiting the supply of meat and fish.

In environmental terms:

- Encourage sustainable mobility = install charging points for electric vehicles in the car park and encourage members to carpool.
- Limiting waste = favouring the use of recyclable products and limiting the use of plastic products as much as possible.
- Preserving the environment = preserving and developing the site's existing biodiversity, limiting the use of physio-sanitary products, reducing the carbon footprint.
- Limiting water consumption = harvesting rainwater, encouraging the recycling of wastewater, choosing suitable grasses.

On a societal level:

- Responsible management of volunteers = rewarding the work of volunteers within the club and encouraging them to take part in federal training courses.

- Raise awareness internally = organise theme days.
- Educate for sustainable development = promote the "*eco-golfer*" communication campaign.
- Seek to obtain "*labels*" = in France, the biodiversity label (bronze, silver, gold) and ISO 14024.

Stage 4. This final stage involves proposing a "*model*" to golf club managers based on that of the FGRFC. Not all clubs can have the same ambitions, depending on the constraints they face. This is why we have chosen to present not one but two models, depending on the level of commitment possible.

The different possible levels of commitment

Depending on their primary vocation, their management style and their location, not all golf clubs can approach the ecological transition in the same way. The motivation of managers can also differ greatly. According to the Agence de la Transition Ecologique[7], four graduated scenarios can be envisaged:

- The first is founded on a (re)evolution in behaviour. New practices, new consumption habits and major transformations in the way we travel, heat and eat are the cornerstones.
- The second is based on a shared determination on the part of all (economic) actors, leading to global cooperation and massive investment in solutions for the future.
- The third assumes that technological progress will make it possible to find solutions to all environmental challenges,
- Finally, the last option envisages a "*status quo*" that will allow current lifestyles to be safeguarded. It assumes massive investment in (non-existent) technologies capable of "*repairing*" the damage caused to the environment by the annoying habits of the past[8].

We do not believe it is necessary to design four different models for golf clubs based on the FGRFC example. On the other hand, this approach highlights the value of proposing graduated models depending on the level of commitment possible and desired by the parties involved. Two models are proposed below. The first is ambitious and constitutes something of a theoretical model. The second is less ambitious. It is based on extending actions that already exist in part. The example of FGRFC helps to bring them together within a coherent framework.

RESULTS

The Ambition+ (AB+) model

The "*Ambition +*" model describes what may be the situation for the majority of tomorrow's golf courses. We are still a long way off from achieving this goal. For the time being, based on the FGRFC model, it presents choices that would make golf courses pioneering sports facilities in this area. It involves abandoning long-standing habits (players) and methods (managers). What is more, some of the investments envisaged are expensive and therefore most certainly out of the reach of golf courses, whose economic equilibrium is fragile. It is therefore a theoretical framework towards which we must try to move.

Adaptation Model (AD)

The adaptation model is simpler to implement and already partially exists in some clubs[9]. It is based on management choices and is, therefore, mainly dependent on the will of the managers.

[7] The Agency for Ecological Transition https://www.ademe.fr/les-futurs-en-transition/les-scenarios/#technologies-vertes
[8] In a not-too-distant perspective, Golf Course 2030, for its part, proposes three possible scenarios for changing weather conditions.
[9] Examples include La Rochelle Sud, Les Alouettes, Vittel Hermitage, La Jonchère, Quiberon, Dinard and Loches

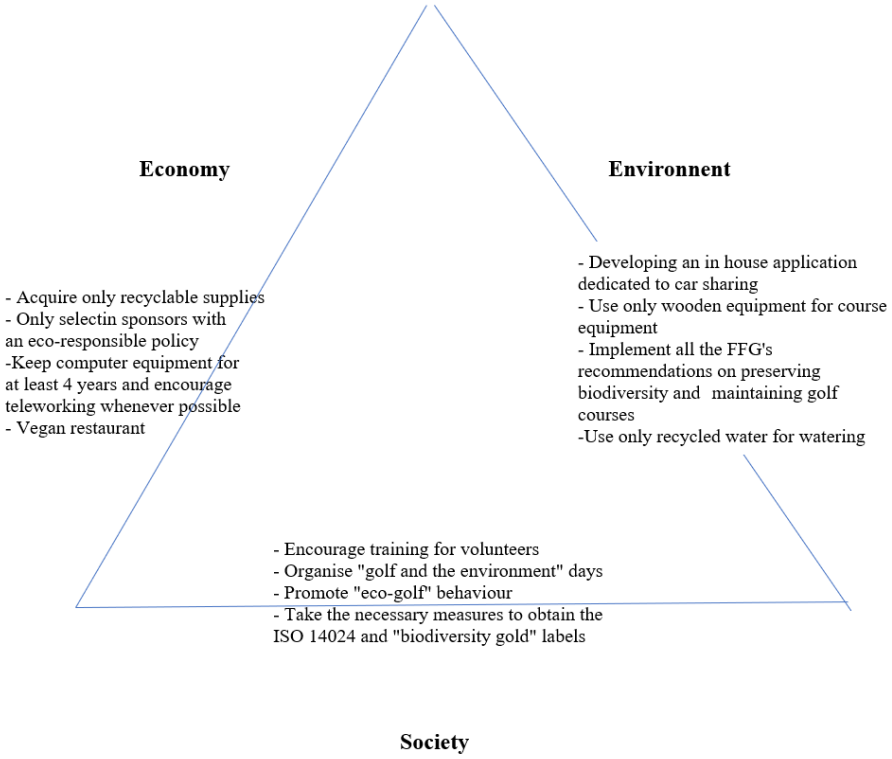

Figure 2. Ambition + model.

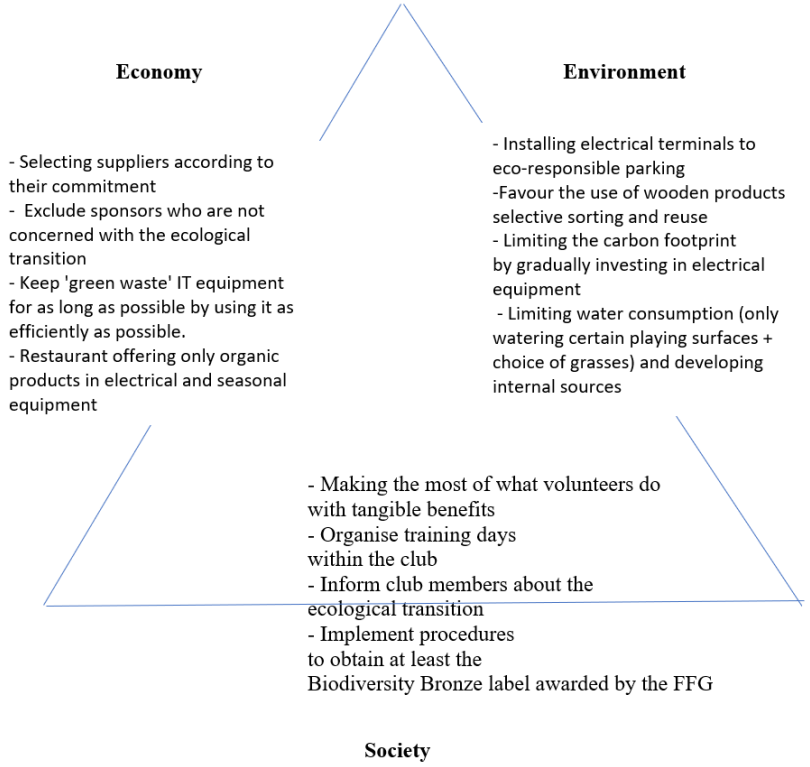

Figure 3. Adaptation model.

DISCUSSION

Although these two models have different ambitions, they are nevertheless built on the same foundations. They share an identical philosophy, but the means envisaged to move towards an eco-responsible model are less drastic in the adaptation model. The latter can therefore be seen as a step towards the former. While some of the actions listed require considerable investment, others are virtually free and could therefore be quickly implemented. In both cases, the main aim is to provide golf managers with an overall framework to ensure that a number of eco-responsible initiatives are not cancelled out by other choices. Sustainability is the guiding principle underlying these proposals. In the short term, to limit the impact of golf on the environment and adapt playing conditions to climate change; in the longer term, to ensure the ongoing future of golf.

Even if they appear to be blueprints for certain proposals, the models proposed do not emphasise the human dimension of this reflection: inclusion, gender equality, accessibility for people with disabilities, etc. should also be taken into account.

In terms of communication, however, the adoption of the adaptation model could enable certain golf managers to choose an original marketing strategy. In the golf sector, the strategic positioning of clubs is most often the result of their location and history. For example, courses that host major international competitions (e.g. the British Open) or that have been around for a long time (e.g. British links) are perceived as prestigious and attractive. Similarly, golf courses close to major conurbations can select their members and adopt an elitist policy. But what about the others? This question is often not considered by managers who do not benefit from a "*natural positioning*". But there are ways of thinking about it. In the wake of numerous studies highlighting the benefits for the physical and mental health of golfers (Driver, 1996; Hume, Keogh and Reid, 2005; Farahmand and al., 2009; Berlin and Klenosky, 2014; Murray and al., 2018), some authors (Breitbarth and Huth, 2019) propose a "*health*" positioning for golf courses that do not benefit from "*natural*" comparative advantages. In the same vein (a combination of the two being perfectly possible), a clearly asserted eco-responsible positioning, along the lines of what exists for the FGRFC, could appeal to "*committed*" golfers who are particularly attached to these issues.

More generally, this type of strategy could certainly help to improve the image of golf, which is often criticised on these issues due to a lack of knowledge of the subject. It is important to highlight that this is just a rough outline in order to give a general overview of the situation. Ideally, it should be extended to overcome some of its limitations.

Limitations of the analysis

Two types of limitations can be mentioned: methodological and general.

Methodological

Our study could have benefited from:

- A larger number of interviews with golf managers. However, one clear trend has already emerged: the need for a global framework for reflection and the limited time available to devote to these issues on a daily basis.
- A real immersion in FGRFC. We considered this, but unfortunately it was not possible for financial reasons.
- The creation of indicators to measure the benefits generated by the proposed actions, but this proved to be too complex for us. However, the study being carried out by the Centre de Droit et d'Economie

du Sport in Limoges[10] in collaboration with the FGF should lead to an overall cost-benefit analysis in this area.

General

- Our work does not provide an estimate of the cost of the measures to be implemented, which is an essential factor in the choice of managers. For France, some of the documents available on the FGF website are a partial substitute.
- Since it is based on the FGRFC model, our proposal does not take up exactly the directions mentioned by Golf Course 2030, the reference document proposed in 2018 by the Royal and Ancient. On closer examination, it is similar in almost every respect, with the exception of multifunctionality.
- The proposed guidelines do not take into account the specific problems associated with the organisation of competitions, particularly international competitions, which are very demanding in terms of playing conditions and course maintenance.

CONCLUSION

A lot has changed since the early 1960s. Today, the ecological transition is a priority for all stakeholders in the golf industry. Several crucial issues have emerged: water, decarbonisation, pesticide use, biodiversity and multifunctionality. The people involved on the ground, i.e. golf course managers, are the most directly concerned, as they have the onerous task of reconciling the need to maintain golfing activities, the ecological transition and economic constraints. Depending on the nature of the facility, not everyone has the same resources to solve this complex equation. Many of them are therefore looking for a formal framework that will enable them to go beyond the implementation of one-off actions to meet all the constraints resulting from climate change and its consequences. Among the various possibilities available to them, the FGRFC model is a particularly interesting one.

Following the approach proposed by Berger-Douce and Durieux Nguyen Tan (2002), it is indeed possible to propose two models that are directly operational for golf course managers and which, in addition to their practical usefulness, can provide them with a focus for innovative positioning. Like other industries, the golf industry is at a crossroads. Like White (2021), we believe that its role could even prove to be a driving force: "*Although sustainability is a lofty goal, it's a huge opportunity for golf, and there are a number of steps that golf courses can take immediately to begin changing for the better. Golf has the potential to set a leading example for how sports can play their part in tackling climate change and will be forced to adapt no matter what. Again, by prioritizing the triple bottom line—people, planet, and profit—golf courses can truly become a force for good*".

SUPPORTING AGENCIES

No funding agencies were reported by the author.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author.

[10] CDES Limoges, The Centre for Law and Economy of Sport.

REFERENCES

Agence de la Transition Ecologique. (2022). Les futurs en transition. Les scénarios.

Andreff, W. (2021). La face cachée du sport-Dérives économiques et scandales financiers. De Boeck Supérieur.

Balogh, J. C., & Walker, W. J. (2020). Golf course management & construction: Environmental issues. CRC Press. https://doi.org/10.1201/9781003070092

Bayle, E., Chappelet, J. L., François, A., & Maltèse, L. (2011). Sport et RSE. Vers un management responsable.

Bayle, E. (2012). Les pratiques de RSE des fédérations sportives. Jurisport, (117), 23-29.

Berger-Douce, S. et Durieux-Nguyen Tan, F. « Le raisonnement par analogie et par métaphore en sciences de gestion », dans Questions de méthodes en Sciences de Gestion, N. Mourgues (dir.), Editions EMS, 2002, p.213-236.

Berlin, K., & Klenosky, D. (2014). Let me play, not exercise! A laddering study of older women's motivations for continued engagement in sports-based versus exercise-based leisure time physical activities. Journal of Leisure Research, 46, 127-152. https://doi.org/10.1080/00222216.2014.11950316

Bizzarri C., "Gli impatti economico-ambientali d elle attività turistiche sulle risorse naturali", in BIZZARRI C., QUERINI G. (a cura di), Economia del turismo sostenibile. Analisi teorica e casi studio, Milano, FrancoAngeli, 2006, pp. 75-95.

Borden, S. (2015). Sundays On the Old Course at St. Andrews: No Golfers Allowed. The New York Times. Retrieved from [Accessed 2025, March 25]: https://www.nytimes.com/2015/06/14/sports/sundays-on-the-old-course-at-st-andrews-no-golfers-allowed.html

Bouvet, P. (2009). Golf et management, Economica.

Breitbarth, T., & Huth, C. (2019). A stakeholder marketing perspective: Golf's potential to (re-) position as a health sport. German Journal of Exercise and Sport Research, 49(3), 351-355. https://doi.org/10.1007/s12662-019-00590-5

Carson, R. (2002 [originally 1962]). Silent Spring. New York: Houghton Mifflin Company.

Cohen, S., Svrjcek, A., Durborow, T., & Barnes, N. L. (1999). Water quality impacts by golf courses. Journal of environmental quality, 28(3), 798-809. https://doi.org/10.2134/jeq1999.00472425002800030010x

Colding, J., & Folke, C. (2009). The role of golf courses in biodiversity conservation and ecosystem management. Ecosystems, 12, 191-206. https://doi.org/10.1007/s10021-008-9217-1

Dal Mas, F., Jupp, W., Massaro, M., Bagnoli, C., & Marseglia, G. R. (2022, September). Corporate Social Responsibility and Intellectual Capital in Sports and Leisure: The case of a Golf Club. In 23rd European Conference on Knowledge Management Vol 1. Academic Conferences and publishing limited. https://doi.org/10.34190/eckm.23.1.161

Dahl Jensen, A. M., Caspersen, O. H., Jensen, F. S., & Strandberg, M. (2017). Multifunctional Golf Facilities as a Resource of Important Ecosystem Services in a Changing Urban Environment: Nordic Case Studies. International Turfgrass Society Research Journal, 13(1), 236-239. https://doi.org/10.2134/itsrj2016.05.0424

Darnall, N., & Sides, S. (2010). Assessing the Performance of Voluntary Environmental Programs: Does Certification Matter? In P. deLeon & J. E. Rivera (Eds.), Voluntary Environmental Programs (pp. 213-238). Lanham: Lexington. https://doi.org/10.5771/9780739133248-213

Driver, B. (1996). Benefits-driven management of natural areas. Natural Areas Journal, 16, 94-99.

Farahmand, B., Broman, G., De Fairel, U., Vagerö, D., & Ahlborn, A. (2009). Golf: a game of life and death-reducedmortality in Swedish golf players. Scandinavian Journal of Medicine and Science in Sports, 19,419-424. https://doi.org/10.1111/j.1600-0838.2008.00814.x

Fédération française de Golf (2022,a). Transition écologique : un plan d'action à la hauteur du défi !.

Fédération Française de Golf (2022,b). Programme & Label Golf pour la Biodiversité : connaître, agir et sensibiliser au patrimoine naturel des golfs.

Fédération Française de Golf (2022,c). Les clés pour engager la transition écologique dans mon golf.

François, A., & Bayle, E. (2014). Analyse des pratiques de RSE des clubs sportifs professionnels français. Revue de l'organisation responsable, 9(2), 5-20. https://doi.org/10.3917/ror.092.0005

François, A. et Boucher, W. (2023). De la responsabilité à l'utilité sociale du sport. L'Harmattan.

FGR Environment report (2017).

Forest Green Rovers (2018), Retrieved from [Accessed 2025, March 25]: https://www.fgr.co.uk/another-way/

Fouillouze, A., Lacoeuilhe, A., & Truong, M. X. A. (2023). A step towards a greener green? Investigating golfers' relationships with nature and attitudes about biodiversity conservation in golf courses. Journal of Outdoor Recreation and Tourism, 43, 100659. https://doi.org/10.1016/j.jort.2023.100659

Golf Business International. (2021), "Corporate and Social Responsibility", Golf education and training, Retrieved from [Accessed 2021, July]: https://golfbusinessinternational.com/golf-education-and-training/corporate-social-responsibility/

Hammond, R. A., & Hudson, M. D. (2007). Environmental management of UK golf courses for biodiversity-attitudes and actions. Landscape and urban planning, 83(2-3), 127-136. https://doi.org/10.1016/j.landurbplan.2007.03.004

Hume, P., Keogh, J., & Reid, D. (2005). The role of biomechanics in maximising distance and accuracy of golf shots. Sports Medicine, 35, 429-449. https://doi.org/10.2165/00007256-200535050-00005

International Golf Federation. (2021), "Corporate Social Responsibility", Sustainability, Retrieved from [Accessed 2021, June 13]: https://www.igfgolf.org/about/social-responsibility

Kourilsky, F. (1990), in Morin, E. (1990). Actes du Colloque du Comité National de la Recherche Scientifique Interdisciplinarité. Introduction. Éditions du CNRS : Paris.

Makowiak, J. (2023). Transitions. Revue juridique de l'environnement, 48, 5-7.

McCarty, L. (2018). Golf turf management. CRC Press. https://doi.org/10.1201/9781351057950

McKeiver, C., & Gadenne, D. (2005). Environmental Management Systems in Small and Medium Businesses. International Small Business Journal, 23(5), 513-537. https://doi.org/10.1177/0266242605055910

Mercatanti L., "Lo sviluppo del turismo del Golf in Sicilia", Geotema, 2017, XXI, 54, pp. 73-80.

Millington, B., & Wilson, B. (2016). Introduction: Approaching golf and environmental issues. In The greening of golf (pp. 3-26). Manchester University Press. https://doi.org/10.7765/9781526107039.00008

Millington, B., & Wilson, B. (2017). The Masters Golf Tournament: Media mega-event, the environment and the emergence of Augusta National Syndrome. In Sport, media and mega-events (pp. 142-155). Routledge. https://doi.org/10.4324/9781315680521-10

Minoli, D. M., & Smith, M. T. (2011). An Exploration of Golf and Voluntary Environmental Programmes. Journal of Environmental Planning and Management, 54(7), 871-889. https://doi.org/10.1080/09640568.2010.539372

Minoli, D. M. (2018). Influences on the Diffusion of Environmental Programmes in Small Businesses in the Greening of an Industry for Sustainability: The Case of Golf. J. Mgmt. & Sustainability, 8, 1. https://doi.org/10.5539/jms.v8n2p1

Murray, A., Archibald, D., Murray, I. R., Hawkes, R. A., Foster, C., Barker,K.,Kelly,P.,Grant, L.,&Mutrie,N. (2018). 2018InternationalConsensus Statement on Golf and Health to guide action by people, policymakers and the golf industry. British Journal of SportsMedicine, 52,1426-1436. https://doi.org/10.1136/bjsports-2018-099509

Nutter, G. C. (1964). The consequence of 'Silent Spring'. The Golf Course Reporter, April, 43-56.

Ostmeyer, T. (2001). Keepers of the green: 75 for 75. Golf Course Management, September, 21-72.

Papp-Vary, A. F., & Farkas, M. (2022). The world's first carbon neutral football club: The case study of Forest Green Rovers. Economic and Social Development: Book of Proceedings, 121-127.

Petrosillo, I., Valente, D., Pasimeni, M. R., Aretano, R., Semeraro, T., & Zurlini, G. (2019). Can a golf course support biodiversity and ecosystem services? The landscape context matter. Landscape Ecology, 34, 2213-2228. https://doi.org/10.1007/s10980-019-00885-w

Ratten, V. and Babiak, K. (2010), "The role of social responsibility, philanthropy and entrepreneurship in the sport industry", Journal of Management and Organization, Vol. 16. https://doi.org/10.1017/S1833367200001875

Ratten, V. (2010). The future of sports management: A social responsibility, philanthropy and entrepreneurship perspective. Journal of Management & Organization, 16(4), 488-494o. 4, pp. 482-487. https://doi.org/10.5172/jmo.2010.16.4.488

Roquinarc'h, O., Lacoeuilhe, A., Gourdain, P., Charrier, T., & Fournil, C. (2019). Le golf: activité sportive contre-nature ou opportunité écologique?. Naturae, (8), 211-232.

Royal and Ancient (2020). Golf Course 2030.

Samuel, A. (2018). Macromarketing insights ninety minutes at a time: A season with Forest Green Rovers, the world's greenest football club.

Scott, D., Rutty, M., & Peister, C. (2018). Climate variability and water use on golf courses: optimization opportunities for a warmer future. Journal of Sustainable Tourism, 26(8), 1453-1467. https://doi.org/10.1080/09669582.2018.1459629

Shaddox, T. W., Unruh, J. B., Johnson, M. E., Brown, C. D., & Stacey, G. (2022). Water use and management practices on US golf courses. Crop, Forage & Turfgrass Management, 8(2), e20182., T. W., Unruh, J. B., Johnson, M. E., Brown, C. D., & Stacey, G. (2022). Water use and management practices on US golf courses. Crop, Forage & Turfgrass Management, 8(2), e20182. https://doi.org/10.1002/cft2.20182

Tanner, R. A., & Gange, A. C. (2005). Effects of golf courses on local biodiversity. Landscape and Urban planning, 71(2-4), 137-146. https://doi.org/10.1016/S0169-2046(04)00034-9

Tidåker, P., Wesström, T., and Kätterer, T. (2017). Energy use and greenhouse gas emissions from turf management of two Swedish golf courses. Urban Forestry & Urban Greening 21, 80-87. https://doi.org/10.1016/j.ufug.2016.11.009

Wheeler, K., & Nauright, J. (2006). A global perspective on the environmental impact of golf. Sport in society, 9(3), 427-443. https://doi.org/10.1080/17430430600673449

White, O. (2021), The Opportunity for Sustainability in Golf, ACER Sustainability.

Zedet, B. (2006). La prise en compte du développement durable au ministère de la Jeunesse, des Sports et de la Vie associative. Cahiers de l'INSEP, 37(1), 229-235. https://doi.org/10.3406/insep.2006.1932