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The Influence of Sports on Executive Functions in Para-Athletes: A Pilot Study

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Abstract- Sports practice can enhance both the physical and psychological abilities of individuals, including executive functions, which may influence other daily activities. This study aims to explore the correlation between sports and executive functions, considering the heterogeneity of results found in existing literature. The present pilot study focused on professional parasports athletes and used the Five-Digit Test (FDT) to measure and compare cognitive performance. This is a cross-sectional study conducted with ten (10) participants, five (5) of whom were elite athletes and five (5) from a sedentary population with disabilities. The results revealed a significant difference in performance between the two groups, particularly in the controlled processes of choice and task-switching. This statistical variation may suggest a potential enhancement in higher-order cognitive functions among the athlete group.

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The Influence of Sports on Executive Functions in Para-Athletes: A Pilot Study

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I. Introduction

Sports encompass various aspects, with each category exhibiting a range of characteristics that define them, allowing classification into open-skill and closed-skill sports. Open-skill sports are characterized by low or no predictability, presenting diverse environments and distinct situations in each match. Conversely, closed-skill sports exhibit a high degree of predictability, with consistent movements across most competitions, reflecting a certain constancy during practice (Heilmann, Weinberg & Wollny, 2022). Furthermore, sports influence the development of various aspects of individuals who engage in them, with more significant evolution observed with prolonged exposure and practice time (Holfelder, Klotzbier, Eisele & Schott, 2020).

Malm, Jakobsson & Isaksson (2019) demonstrate in their meta-analysis the multiple benefits of sustained sports practice in areas such as aerobic exercises or weight training for sedentary individuals undergoing routine changes or elderly individuals in similar practice scenarios. Examples of such benefits include reduced incidence of type 2 diabetes, cardiovascular diseases, depression, dementia, and obesity. The authors also highlight improvements in sleep quality, muscle mass gain, and bone density acquisition.

Cognitive aspects are also modified as sports exposure occurs. Kopp & Jekauc (2018) show in their study the importance of emotions in generating environmental assessments, activating physiological aspects required during matches, and influencing decision-making. This suggests a weak association between emotional intelligence and high performance in sports. In turn, Fontani, Lodi, Felici, Migliorini & Corradeschi (2006) present in their research that high-performance sports exhibit elevated results regarding response time, including divided and selective attention, demonstrating low inaccuracy during plays and indicating maturation of movements and attention concerning the sport.

Moreover, research indicates the influence of sports on language functions, such as verbal fluency and verbal memory, for high-performance athletes compared to retired athletes, with data pointing to a

decline in such functions over time due to the lack of sports practice in retired athletes (Prien, Demont, Verhagen, Twisk & Junge, 2020).

Similarly, literature shows an increasing number of studies regarding the relationship between executive functions (EF) and sports, defining the former as higher-order cognitive functions unique to the human species. These can be divided into core executive functions, such as inhibitory control, working memory, and cognitive flexibility, and higher-level executive functions, such as reasoning and problem-solving. Thus, EFs are complex psychological processes aimed at identifying, understanding, formulating, and solving problems, as well as executing behavior in response to environmental stimuli (Xue, Yang & Huang, 2019; Doebel, 2020; Takacs & Kassai, 2019; Heilmann et al., 2022; Gilbert & Burgess, 2008).

Executive functions are examined in child athletes, showing indications of this relationship, where children and adolescents practicing sports, primarily open-skill sports, tend to score higher in areas such as inhibitory control compared to non-athlete peers of the same age (Xue et al., 2022; Holfelder et al., 2020). Similarly, according to Giordano, López & Alesi (2021) and Ishihara, Sugasawa, Matsuda & Mizuno (2017), closed-skill sports, like martial arts, favor the development of functions such as working memory and inhibitory control in young boxers compared to non-athletes. Training strategies can also supplement the development of executive function skills in youth, such as High-Intensity Interval Training, used by young athletes in weight training and aerobic exercises, showing positive results concerning EFs (Leahy et al., 2020).

In their work, Scharfen & Memmert (2019) indicate the effects of sports in three categories of athletes: low-performance, high-performance, and elite. Elite athletes are active professionals with a high weekly training load, and this category shows a significant moderate degree of benefits in executive functions without age discrimination among participants. Similarly, Koch & Krenn (2021) exhibit a statistical difference between elite athletes separated into open-skill and closed-skill groups. Even with a small sample studied, the first group mentioned earlier shows a significant property concerning EFs compared to control groups that do not habitually practice sports. Consistently, research by Lundgren, Hogman, Naslund & Parling (2016) indicates that professional league hockey players validate the aforementioned findings, where elite sports categories score higher on instruments like the Delis-Kaplan Executive Function System compared to the sedentary population studied.

Recent research also validates the benefits of physical training for senior individuals. Regardless of training time, intensity, and duration of practices, the effects were positive and slightly significant compared to the sedentary population of the same age (Chen, Etnier, Chan, Chiu, Hung & Chang, 2020). In studies like Tarumi et al. (2022), improvements in cognitive skills and their processing, including EFs, are noted, supported by the performance of physical activities, highlighting the relevance of physical exercise performance for the elderly.

The present research is justified by the need for in-depth studies on the subject due to its great value and importance, as well as the necessity to find therapeutic strategies that contribute in some way to people's quality of life, considering the benefits and influences that physical activity practice positively has on EFs. The focus of this work is the comparison of EFs between the sample of para-athletes and the control group. Since processing speed is a key factor for para-athletes, finding strategies to measure, evaluate, and improve EFs is paramount, considering that studies like Russo et al. (2010) expose the benefits of open-skill sports practice for the para-athlete population, making it essential to deepen the topic for the improvement of para-sports practice.

Therefore, sport is understood not only as a leisure activity or profession but also denotes benefits for multiple aspects of health. Thus, it is necessary to understand sports activity in para-athletes, aiming to expand knowledge regarding the executive functions of the desired audience. As Mangueira, Felisberti, Barboni, Costa & Grossklauss (2022) demonstrate a deficit in executive subfunctions such as working memory in patients with muscular dysfunction, the need for understanding grows for Individuals with muscular dysfunction often exhibit deficits in executive subfunctions, such as working memory. This underscores the growing need for scientific understanding regarding the nature of such dysfunctions and the potential benefits of sports participation.

The present study aimed to compare the influence of athletic practice on executive functions in elite para-athletes with muscular dystrophy engaged in boccia and table tennis, focusing specifically on core executive functions (EFs). To this end, a cross-sectional study was conducted with two groups diagnosed with Becker Muscular Dystrophy (BMD): one composed of athletes and the other of sedentary individuals. The comparison was carried out using the Five Digits Test (FDT), based on the hypothesis that elite athletes would perform better on tasks involving decision-making, task-switching, inhibition, and cognitive flexibility than their sedentary counterparts.

BMD is a subtype of muscular dystrophy within the spectrum of degenerative muscular diseases. It is inherited in an X-linked recessive pattern and leads to partial or complete loss of control over the musculoskeletal system. This results in a gradual decline in the functionality of both upper and lower

limbs, and the condition is more prevalent in males (Salari et al., 2022).

II. Methodology

a) Study Design

This research employed a quantitative, exploratory, and cross-sectional design. The methodology was chosen in accordance with the research objectives, taking into consideration the limited sample size available and the high demand for studies in this field. Ethical guidelines for psychological research established by the American Psychological Association (APA, 2017) were followed throughout the study.

b) Participants

Participants were selected through convenience sampling, and the sample met the following inclusion criteria: aged between 20 and 65 years; engagement in closed-skill sports such as boccia and table tennis at least three times a week for a minimum of six months; diagnosed with muscular dystrophy; of either sex; and fluent in Portuguese.

For the control group, inclusion criteria were similar: aged between 20 and 65 years; of either sex; diagnosed with muscular dystrophy; and fluent in Portuguese.

The final sample comprised five (5) native Brazilian individuals engaged in sports such as boccia and table tennis, participating in training at least three times per week, and aged between thirty (30) and sixty-five (65) years. The control group also consisted of five (5) native Brazilians within the same age range, selected from a center for individuals with physical and intellectual disabilities in the city of Curitiba.

c) Ethical Considerations

The project was submitted to and approved by a Research Ethics Committee, under protocol number CAAE: 68541123.2.0000.8040. Data collection was conducted only after obtaining the required ethical clearance.

d) Procedures

All participants and, when necessary, their legal guardians were contacted, informed about the research, and signed an informed consent form in accordance with national ethical guidelines for research involving human subjects (Brazilian Ministry of Health, Resolution 466/2012). Additionally, the administrators of the parasport institution provided a signed declaration of infrastructure availability, allowing the study to be conducted on their premises.

The data collection took place in a private room within the institution, previously prepared for the administration of the research instruments. After complete data collection, responses were tabulated using Microsoft Excel. The data were subsequently analyzed using the quantitative analysis software Jamovi (version 2.3.26).

Regarding data integrity, no missing values were identified, and all responses exceeding the study average were retained, as their inclusion did not compromise the analysis. On the contrary, excluding such data could lead to misinterpretation of the findings. Data were matched and analyzed using Jamovi (version 2.3.26).

e) Instruments

The interviews lasted between ten (10) and twenty-five (25) minutes, beginning with a socio-demographic questionnaire to familiarize participants with the research process and to collect relevant data, including information on age, nationality, education level, and involvement in closed-skill sports. Specific questions addressed the frequency of sports participation, number of years as a sports practitioner, and years of formal education (Pereira et al., 2018).

Following this, the *Five Digits Test* was administered to assess processing speed, executive attention, cognitive flexibility, and reading and counting processes. This instrument is particularly suitable for individuals with low educational backgrounds, a factor relevant to the scope of the current study (Campos et al., 2016).

The initial hypothesis proposed a significant effect in comparing the performance of adults with muscular dystrophy who engage in sports to those who are sedentary, particularly in their results on the Five Digits Test.

III. Results Analysis

The mean age of participants in the control group was 48.4 years, whereas the mean age in the experimental group was 38.8 years. The average duration of participation in closed-skill sports among the experimental group was 14.6 years, with a standard deviation of 1.44 years. Participants in this group reported engaging in their respective sports between four (4) and five (5) times per week, with an average of 4.2 days (Table 1).

Table 1: Sociodemographic Data of the Experimental and Control Groups

Group	Age	Years of Formal Education	Frequency of Practice (Days)	Years of Sports Practice
Experimental	38.8 (7.26)	9.20 (1.64)	4.20 (0.447)	14.6 (3.21)
Control	48.4 (12.9)	7.60 (3.51)	0.00 (0.00)	0.00 (0.00)

Data were entered into Jamovi software for analysis. A pairwise comparison method was used to compare the means between groups, calculating p-values with a 95% confidence interval. Subdomains of executive function that showed statistical significance included both automatic processes (e.g., counting) and controlled processes (e.g., decision-making and cognitive flexibility), with strong correlations based on Spearman's rank correlation coefficient (Table 2).

Table 2: Spearman's Rank Correlation Coefficient

Variable	Spearman's ρ	*p*-value
Years of Sports Practice × Counting Time	0.913	0.030
Sports Practice × Choice Time	-0.289	0.638
Sports Practice × Alternation Time	-0.289	0.638
Sports Practice × Flexibility Time	-0.577	0.308

A significant difference emerged at the beginning of the third task, which marked the transition from automatic to controlled functions. This task required greater attentional demand, focusing on quantity-based counting rather than numerical symbols. The performance gap widened with increasing task complexity. Para-athletes not only made fewer errors but also showed superior abilities in tasks assessing cognitive flexibility and decision-making compared to the control group.

Table 3: Wilcoxon-Mann-Whitney Mean Comparison

Variable	Statistic	*p*-value
Sports Practice × Reading Time	Wilcoxon W = 0.00	0.058
Sports Practice × Choice Time	Wilcoxon W = 0.00	0.058
Formal Education × Reading Time	Wilcoxon W = 0.00	0.063
Formal Education × Choice Time	Wilcoxon W = 0.00	0.063

Statistically significant correlations were observed between years of sports practice and formal education, particularly in the Spearman analysis (p = 0.030). These results suggest a relationship between athletic engagement and improved performance in controlled cognitive processes, a finding reinforced by the Wilcoxon-Mann-Whitney tests, which demonstrated notable effects in tasks involving reading and decision-making.

IV. Discussion: The Benefits of Closed-Skill Sports on Executive Functions in Para-Athletes

This study investigated the cognitive benefits associated with participation in closed-skill sports, such as table tennis and boccia, among individuals with disabilities. Findings indicated significant improvements in both automatic processes (e.g., counting) and controlled executive functions (e.g., decision-making and task switching), especially among participants with higher levels of education and prolonged engagement in sport practice. These results align with the hypothesis that structured, predictable sports environments offer an ideal context for enhancing executive functions in populations with cognitive vulnerabilities.

Previous research has yielded mixed findings regarding the cognitive outcomes of athletic involvement among individuals with disabilities. Studies by Di Russo et al. (2010) and Cutuli (2020) demonstrated enhanced decision-making and cognitive flexibility in para-athletes with intellectual disabilities. Conversely, Pinilla et al. (2016) observed lower cognitive performance among wheelchair basketball players compared to able-bodied peers. However, the present study aligns with more recent evidence from Wang, Wu, and Chen (2023), who found significant gains in working memory and inhibitory control following short-term engagement in closed-skill sports.

A consistent theme across the literature is the moderating role of educational background and cumulative athletic experience. Koch and Krenn (2021) emphasize that both the type of sport and the athlete's history of participation significantly influence cognitive outcomes. Our findings corroborate this, showing that athletes with more years of practice and higher

educational attainment exhibited superior executive performance. These findings reinforce the need for inclusive educational and athletic policies that provide sustained access to structured physical activities.

From a theoretical standpoint, executive functions are understood as higher-order mental processes responsible for goal-directed behavior, adaptive planning, and cognitive regulation (Gilbert & Burgess, 2008). Doebel (2020) further asserts that executive functions are dynamic and context-dependent, shaped by individual goals, environmental structures, and social expectations. In this context, closed-skill sports provide a repetitive and stable framework that may facilitate the reinforcement of these cognitive skills over time.

The interplay between sport participation and academic outcomes has also been explored by Giordano, Gómez-López, and Alesi (2021), who reported positive associations between executive function development and school performance, particularly in children involved in structured physical activities. Their findings have important implications for youth and adults with disabilities, who often face systemic barriers to education and inclusion.

Heilmann, Weinberg, and Wollny (2022) synthesized these insights in a meta-analysis comparing open- and closed-skill sports. Their results demonstrated that closed-skill sports tend to elicit more consistent improvements in executive functioning, suggesting that environmental predictability and reduced cognitive load may play crucial roles in facilitating neural adaptation.

While the present study emphasizes the advantages of closed-skill sports, it is essential to contextualize these findings within the broader literature on athletic expertise and attentional performance. Fontani et al. (2006) showed that athletes in open-skill sports develop heightened attentional readiness, though they also acknowledged that expertise level, regardless of sport type, contributes substantially to cognitive performance. This supports our conclusion that extended sport involvement is a key determinant of cognitive development.

Lundgren et al. (2016) provided further evidence from elite ice hockey players, demonstrating improvements in executive functions attributable to high-performance environments. However, Holfelder et al. (2020) introduced a distinction between "hot" and "cool" executive functions, suggesting that sport-specific cognitive benefits may vary depending on emotional and motivational demands. This differentiation is vital for interpreting sport-related cognitive outcomes in both elite and recreational athletes.

Moreover, Ishihara et al. (2017) found that participation in tennis—a semi-open skill sport—was positively associated with executive functioning in youth populations. Their findings indicate that even sports with moderate environmental variability can promote executive development, underscoring the role of task complexity and adaptability.

Collectively, the literature affirms that while the cognitive benefits of sport are well-established, their magnitude and nature are influenced by multiple factors, including sport typology, expertise level, duration of engagement, and individual developmental profiles. This underscores the importance of adopting a context-sensitive and multi-dimensional approach to researching executive functions in athletic settings.

Although the sample size in the current study was limited, the data suggest that closed-skill sports can foster executive function development to a degree that may equal or even exceed that of non-disabled populations. Contributing factors may include the cognitive demands of skill refinement, consistency of training routines, and the motivational climate of inclusive sports programs.

In summary, the findings advocate for the expansion of structured physical activity programs tailored to individuals with disabilities. Given the observed improvements in working memory, inhibitory control, and cognitive flexibility, integrating closed-skill sports into educational, clinical, and community frameworks appears both evidence-based and ethically imperative. Continued interdisciplinary research will be essential to refine our understanding of how specific sport characteristics interact with cognitive development across diverse populations.

V. Conclusion

The findings of the present study suggest that para-athletes engaged in closed-skill sports demonstrate superior performance in controlled executive functions, such as decision-making, task switching, and cognitive flexibility, when compared to sedentary individuals with disabilities. However, such differences were only observed in more complex tasks, particularly those requiring inhibitory control and cognitive flexibility, possibly indicating greater adaptive capacities in the athletic group.

One methodological limitation of the study was the relatively small sample size, which may have led to overestimated effects and potential false negatives. Future studies with larger samples could help clarify the relationship between cognitive processes and sports participation in athletes with disabilities, providing more statistically robust results and enhancing predictive validity.

It is recommended that future research adopt longitudinal designs and larger samples to better understand the long-term cognitive benefits of sports participation in this population and assess the sustainability of these effects over time.

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