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COGNITIVE ASSESSMENT AND PHYSICAL PERFORMANCE IN PROFESSIONAL WHEELCHAIR BASKETBALL PARA-ATHLETES

AVALIAÇÃO COGNITIVA E DESEMPENHO FÍSICO EM PARATLETAS PROFISSIONAIS DE BASQUETE EM CADEIRA DE RODAS

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ABSTRACT

Objective: To assess the cognitive, physical, and emotional factors of professional wheelchair basketball (WB) para-athletes from the Brazilian men's national team in comparison with sedentary non-wheelchair users. Methodology: This is a cross-sectional study including 12 WB para-athletes (G1) and 13 sedentary non-wheelchair individuals (G2) as a control group. Cognitive assessment was conducted using the NeuroSports Arena® software through virtual reality goggles, which measured the variables reaction time (RT) and decision time (DT), reaction quality (RQ) and decision quality (DQ), attention (AT), impulsivity control (IC), and peripheral vision (PV), based on simple reaction and Go/No-Go tasks. Additionally, the software evaluated emotional factors and mood, such as current mood, stress, readiness, and sleep quality from the previous night. Physical assessment included the 20-meter acceleration test, the Yo-Yo Intermittent Endurance Test Level 1, and the Running Anaerobic Sprint Test (RAST). Results and Discussion: No statistically significant differences were found between groups. However, several within-group correlations were identified. Conclusion: No statistically significant differences were found between groups; however, within G1, correlations were observed between cognitive and physical performance, as well as between emotional factors and cognitive performance.

Keywords: Basketball; Para-Athletes; Wheelchairs; Cognition; Physical Functional Performance.

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RESUMO

Objetivo: Avaliar as habilidades cognitivas, físicas e fatores emocionais de para-atletas profissionais de basquetebol em cadeira de rodas (BCR) da seleção brasileira masculina em comparação com indivíduos sedentários não cadeirantes. Metodologia: trata-se de um estudo transversal, incluindo 12 para-atletas de BCR (G1) e 13 indivíduos sedentários não cadeirantes (G2) como grupo controle. A avaliação cognitiva foi realizada utilizando o software NeuroSports Arena ®, por meio de óculos de realidade virtual, que mensurou as variáveis tempo de reação (TR) e tempo de decisão (TD), qualidade de reação (QR) e qualidade de decisão (QD), atenção (AT), controle da impulsividade (CI) e visão periférica (VP) e é baseado em tarefas de reação simples e Go/No-go. Além disso, o software também avaliou fatores emocionais e humor, como o humor, estresse e disposição no momento e a qualidade de sono na noite anterior. Na avaliação física, foram adotados o teste de aceleração de 20 metros, o YoYo Intermittent Endurance 1 e o Running Anaerobic Sprint Test (RAST). Resultados: Não foram encontradas diferenças estatisticamente significativas entre os grupos. Entretanto, foram evidenciadas diversas correlações intragrupos. Conclusão: Não foram encontradas diferenças estatisticamente significativas entre os grupos; entretanto, dentro do G1, foram observadas correlações entre desempenho cognitivo e físico, bem como entre fatores emocionais e desempenho cognitivo.

Palavras-chave: Basquete; Paratletas; Cadeira de Rodas; Cognição; Desempenho Físico Funcional.

1 INTRODUCTION

1.1 Development

Wheelchair basketball (WBC) originated in 1946 as a way to rehabilitate a wounded World War II soldier in the United States (Najafabadi *et al.*, 2023). It has been a Paralympic sport since the inaugural Paralympic Games in Rome (Glattke; Tummala; Chhabra, 2022), and its practice is global, with approximately 100,000 players at various levels, from recreational to professional national teams, making it one of the most popular Paralympic sports (Da Silva *et al.*, 2022).

Among its many advantages, it has the potential to improve muscle strength, endurance, and cardiovascular fitness, while also decreasing the prevalence of chronic physical disorders. From a psychological standpoint, BCR helps alleviate anxiety and feelings of depression, improve sleep, and create and enhance social relationships (Najafabadi *et al.*, 2023).

In this context, an experimental study stated that cognitive measures have the greatest influence on reactive agility performance in typical male basketball players (Scanlan *et al.*, 2014). However, no studies have yet been found that specifically evaluate cognitive domains in the BCR population.

A systematic review observed that the most commonly used instruments for assessing cognitive domains use the conventional paper-and-pencil method (Falck; Davis; Liu-Ambrose, 2016). But, with the advancement of technology, other devices are being adopted, such as smartwatches, for assessing cognitive domains related to memory, attention, and executive function (Adams *et al.*, 2023; Chinner *et al.*, 2018; Hafiz; Bardram, 2020), and virtual reality (VR) (Freeman *et al.*, 2017; Millman *et al.*, 2021; Wiebe *et al.*, 2022)for assessing spatial memory, egocentric and allocentric navigation, and activities of daily living (Jin; Pilozzi; Huang, 2020).

Despite the demands for speed, agility, strength, power, endurance, technical and tactical skills necessary for good performance in BCR, athletes may have suffered from various comorbidities and levels of disability, which leads to variations in performance capacity (Gil *et al.*, 2015). Considering the different physiological and biomechanical demands, the International The Wheelchair Basketball Federation (IWBF) has developed basic motor criteria for sports eligibility, such as muscle strength and reduced passive range of motion, hypertonia, etc. Wheelchair Basketball Federation, n.d.).

However, cognitive variables have been little investigated to date (Campbell; Jones, 2002; Martin, 2008; Silva *et al.*, 2025), although it is understood that, for example, individuals with chronic spinal cord injury have a distinct cognitive profile, with lower scores compared to patients with subacute spinal cord injury (Molina-Gallego *et al.*, 2021).

A practical and engaging assessment of cognitive performance through computerized testing can be an accurate alternative for cognitive screening (Fredrickson *et al.*, 2010). Therefore, the aim of this study was to evaluate the cognitive, physical, and emotional abilities of professional wheelchair basketball athletes from the Brazilian men's national team compared to sedentary, non-wheelchair-using individuals.

2 PROCEDURES AND METHODS

2.1 Study design

This is a cross-sectional study aimed at comparing cognitive variables of professional Paralympic wheelchair athletes with sedentary individuals. This study was approved by the Research Ethics Committee of the Federal University of Triângulo Mineiro (UFTM) (CA-AE:66414122.3.0000.5154).

2.2 Location where the research was conducted

The study was conducted at the Brazilian Paralympic Center (CPB) in São Paulo, during the Americas Basketball Cup in BCR, and developed in the city of Uberaba in Minas Gerais at the Laboratory of Neuroscience and Motor Control (NeuroCom) of UFTM.

2.3 Eligibility criteria

The eligibility criteria for group 1 (G1) were: being a professional para-athlete and member of the Brazilian national basketball team in BCR, male, of any age, and healthy. Group 2 (G2) consisted of sedentary male individuals matched in age and body mass index (BMI) with the group of para-athletes.

Both groups should include literate individuals with adequate scores on the Mini-Mental State Examination (MMSE) of < 20 for individuals with 1 to 4 years of schooling, < 25 points with 5 to 8 years of schooling, < 26.5 points with 9 to 11 years of schooling, and < 29 points with more than 11 years of schooling (Folstein; Folstein; McHugh, 1975), without physical or visual limitations that would prevent them from performing the cognitive examination with the VR device, such as motor impairments in the upper limbs that would compromise the correct handling of the equipment and uncorrected visual acuity deficits.

Individuals who were unable to complete the full assessment due to adverse events such as dizziness, nausea, headache, or others, or who did not comply with any item of the assessment protocol suggested by the equipment manufacturer, were excluded.

2.4 Sample

Group 1 (G1) consisted of 12 Paralympic athletes from the Brazilian men's BCR team, and Group 2 (G2) consisted of 13 sedentary males. Data obtained from the *software* , encompassing the average of all evaluated individuals, were used as the population reference value for AC.

2.5 Procedures

Group 1 (G1) was invited to participate in the research through the dissemination of the project to the team coordinators and technical committee, highlighting the importance of the study in the development of national Paralympic sport. Group 2 (G2) was recruited through social media.

After expressing interest in participating, they were registered using an electronic form containing personal information, anthropometric data, level of education, level of physical activity, and time spent practicing BCR (Brazilian Cross-Country Sports). All individuals were registered on a digital platform and scheduled a time between the participant and the researcher for clarification, signing the Informed Consent Form, and subsequently undergoing the evaluation.

The individual assessment process was organized into the following stages: identification of personal data, anthropometric data, clinical history, level of physical activity, frequency of training per week, years of BCR practice, physical, technical, and cognitive performance assessment using immersive VR. The data characterizing the groups are presented in Table 1.

2.6 Physical assessment

2.6.1 20-meter acceleration test

The para-athletes, seated in their respective wheelchairs adapted for BCR (Brachial Cardiology Rehabilitation), were instructed to perform three sprint attempts at their maximum acceleration and speed over 20 meters, with approximately 120 seconds of rest between each attempt (Gaya; Gaya, 2016; Gorostiaga *et al.*, 2009; Lockie *et al.*, 2012).

They started 0.5 meters behind the starting line marked on the ground; as soon as they crossed the starting and finishing marks, the stopwatch was activated and deactivated, respectively (Fang; Jiang, 2024; PROESP-BR, *[S.d.]*). The outcome measure involved the average time elapsed in the test (in seconds and hundredths of seconds). The same was performed by sedentary individuals; however, they ran normally.

2.6.2 YoYo Test Intermittent Endurance 1 (YYIE1)

The main objective of the test was to measure the aerobic endurance capacity of individuals when repeatedly performing intense exercise, as well as their potential for rapid recovery from this exercise, through cardiorespiratory capacity, also understood as maximum oxygen uptake (VO2max) (Krustrup *et al.*, 2006).

Para-athletes, seated in their respective wheelchairs adapted for cardiopulmonary rehabilitation (CPR), are instructed to cover a distance of 20 m, there and back, and after this return trip, they run five meters for active recovery for 10 seconds, waiting at the starting line for another run. The test is performed at a progressive pace, increasing in response to audible signals automatically emitted by a device (Ravagnani; Borges; Dos Reis, 2022). Sedentary individuals performed the same test, but ran normally.

The test begins at a speed of 8 km/h with a gradual increase of 0.25 km/h (Bangsbo; Iaia; Krustrup, 2008). It is organized with 12 medium cones placed facing each other at a distance of 20 m, forming six "lines" or five "lanes". Small cones will be placed 5 m behind the starting line to delineate the rest area (10s) between runs (Ravagnani; Borges; Dos Reis, 2022).

Its outcome measure is given by the formula VO2max (ml.kg-1.min-1) = total distance covered (in meters) x 0.0084 + 36.4 (Ravagnani *et al.*, 2022).

2.6.3 Running Anaerobic Sprint Test (RAST)

To assess the anaerobic performance of athletes, the RAST provides measurements of important variables such as indirect horizontal power in running with the variables peak power (PP) and minimum power (PMin) and fatigue index (IF) during maximal efforts through sprints.

In this study, we used an adaptation of the test. The para-athletes, seated in their respective wheelchairs adapted to the BCR (Brachial Wheelchair Control), performed only one attempt, in which they executed six sprints, with a passive recovery of 10 seconds, over a distance of 20 meters (Draper; Whyte, 1997; Ravagnani; Borges; Dos Reis, 2022). Two other markers were placed 2 meters after the end of the initial marking to prevent the para-athlete from decelerating before the end point (Ravagnani; Borges; Dos Reis, 2022). Sedentary individuals also performed the test, but ran normally.

Before the test, everyone was instructed to reach the markings in the shortest time possible, going over the entire line with their chair, and then 10 minutes were dedicated to warming up, performing 3 to 5 sprints every 2 minutes. Immediately before the test, the instructions were reviewed until everyone was completely clear (Weber *et al.*, 2021).

The formulas for PP, PMin, and IF are defined as (Zagatto; Beck; Gobatto, 2009)follows: PP (W) = (body mass x distance^2) / fastest sprint time^3

PMin (W) = (body mass x distance ^{2})/ slowest sprint time^3

IF (%) = (peak power - minimum power) / total time to complete the six sprints

2.7 Cognitive assessment

The assessment of cognitive skills was conducted using the NeuroSport app. Are-na® was (Sensorialsports, *[S.d.]*) developed specifically for the context of sports and physical exercise. It is an application for immersive VR glasses that assesses 7 cognitive abilities: reaction time (RT), reaction quality (RQ), decision time (DT), decision quality (DQ), attention (AT), impulse control (IC), and peripheral vision (PV), through a test composed of 4 levels and lasting approximately 25 minutes.

This assessment is characterized by simple reaction and Go/ No-go subtasks. (Van Royen *et al.*, 2022) based on visual stimuli. The stimuli are presented in different positions in the screen's visual field in a random order, and the response is captured by clicking on the hand control.

The researcher underwent specific training for the proper handling of the equipment and software. Therefore, they were responsible for configuring the glasses, logging in with each individual's email and password, verifying their registration data, and explaining the evaluation procedures.

After the explanation, they put on the glasses and, on the immersive screen, completed a brief anamnesis, answering questions related to body mass, height, level of education, type of physical exercise, frequency of physical exercise per week, whether they used medication, and whether they had any visual impairment (if necessary, the assessment could be performed with corrective glasses). Then they answered questions considering the moment of the assessment, such as their mood, disposition, the quality of their last night's sleep, and stress level. All these personal aspects were evaluated using a visual analog scale ranging from zero (very poor) to one hundred (very good).

These periods were considered to be for familiarization with the equipment, in addition to text and audio tutorials guiding individuals at each level.

These are guidelines from the NeuroSport Arena® software (Sensorisports , n.d.) for conducting the assessment: be focused during the assessment, without being preoccupied with other tasks, conduct the assessment in a distraction-free environment, use headphones, be comfortable (appropriate clothing, not sleepy, and having eaten properly), and complete the assessment from start to finish in a single session.

2.7.1 Assessment steps using NeuroSports Arena® software

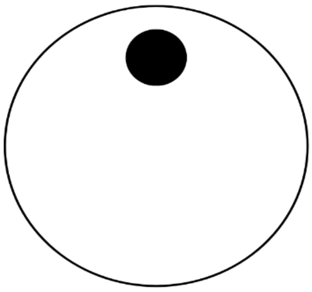
Level 1: The participant was to hold the controller with their dominant hand and use their thumb to click whenever the target image appeared on the screen (Figure 1). They were instructed to maintain focus and be quick. This level contained only one series.

Level 2: The participant was to hold the controller with their dominant hand. At this level, there were three identical series, with two circles that differed from each other (Figure 2), and the participant was to click only when the target figure appeared, so that when the non-target figure appeared, they should not click (Go-No /Go). At this level, there were more circles for the individual not to click than to click. They were instructed to maintain attention and be quick.

Level 3: The participant was to hold the controller with their dominant hand. This level also contained three identical series, with the same dynamics as level 2, but the target circle appeared more times than in level 2, therefore requiring pressing the controller button more times (Figure 2). Participants were instructed to maintain attention and be quick.

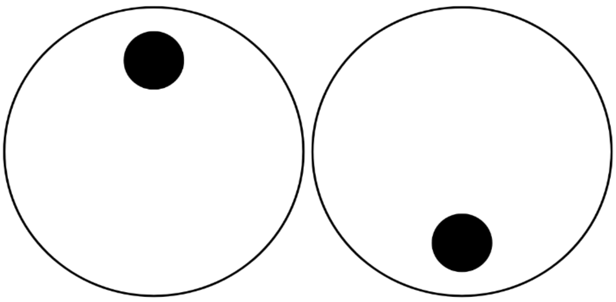
Level 4: The participant should hold the controller with their non-dominant hand and perform the same activity as in level 1, where only one target appears (Figure 1), clicking whenever the target figure appears on the screen. This level contains only one series. Participants controlled the start of each level's series by clicking on the manual controller.

Figure 1 - Appearance model of levels 1 and 4



Source: author's own elaboration, 2025

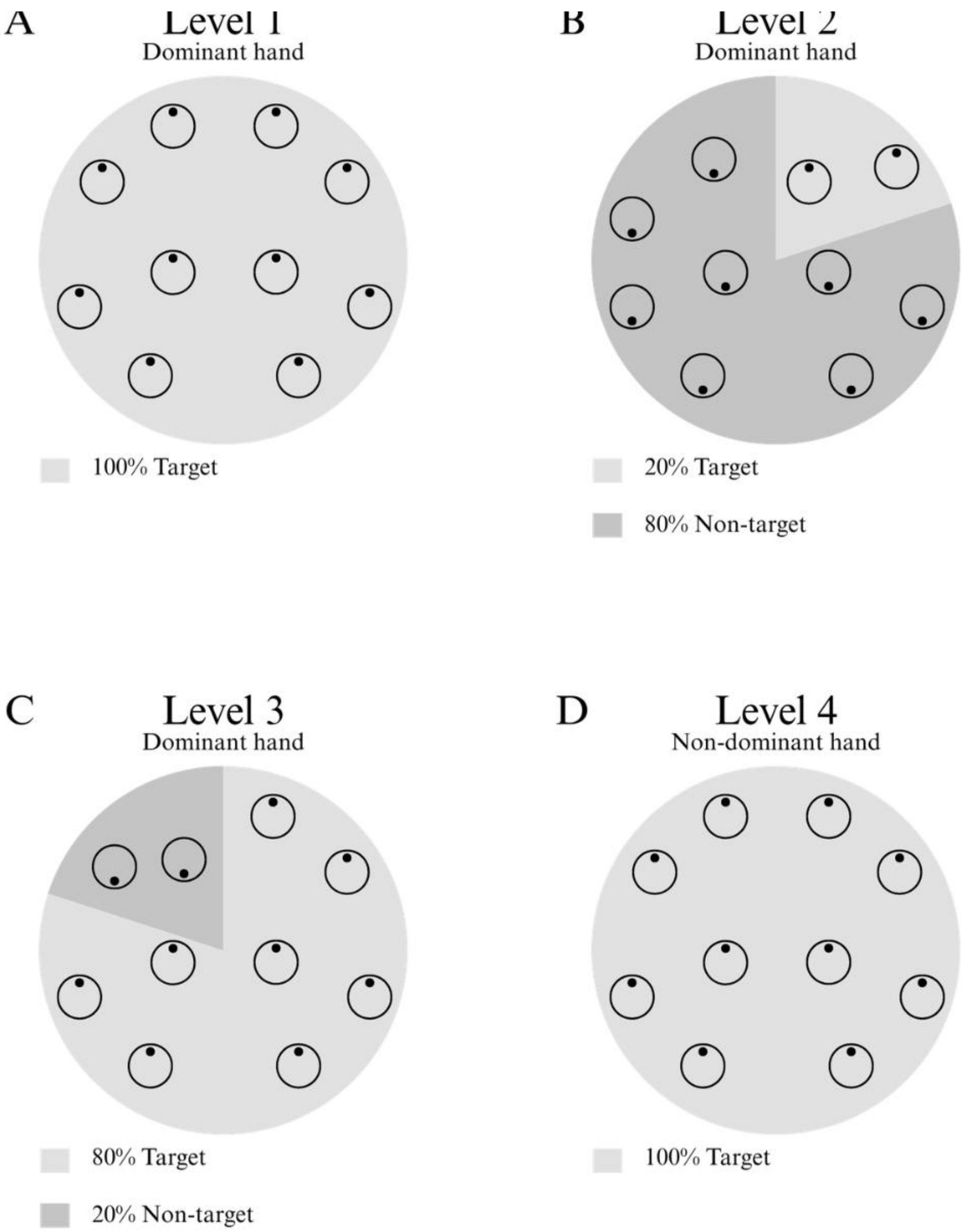
Figure 2 - Appearance model of levels 2 and 3



Source: author's own elaboration, 2025

The frequency of stimulus appearance at level 1 was 90 repetitions, with 100% of the response to the target being a click on the control with the dominant hand. Level 2 had 190 repetitions divided into three subsets, with 80% non-target and 20% target. Level 3 also had 190 repetitions divided into three subsets, with 20% non-target and 80% target. Level 4 contained 90 repetitions, with 100% of the response to the target being a click on the control with the non-dominant hand, as shown in Figure 3.

Figure 3 - Representation of stimuli at the 4 levels of AC



Note: A – Level 1: 100% target with the dominant hand; B – Level 2: 20% target and 80% non-target with the dominant hand; C – Level 3: 80% target and 20% non-target with the dominant hand; D – Level 4: 100% target with the non-dominant hand.

Source: author's own elaboration, 2025

The individuals were informed that they could interrupt the assessment at any time. In that case, the assessment completed without a conclusion would not be included. At the end of the assessment, all participants received a cognitive performance report with the scores obtained for the evaluated variables.

2.7.2 Variables assessed using NeuroSports Arena® software

The abilities assessed by the NeuroSports Arena® software were TR, QR, TD, QD, AT, CI, and VP. These abilities are variables of cognitive function that refer to mental processes of knowledge acquisition (Lezak *et al.*, 2012).

Reaction time (RT): can be defined as the time (in milliseconds) that elapses from the appearance of a stimulus until a response is given, that is, it is the ability to respond quickly to environmental stimuli (Lopes Macedo *et al.*, 2019). According to the software used, the score calculation considers the average reaction time, that is, the interval between the presentation of the visual stimulus and the tactile motor response performed on the hand sensor.

Based on this variable, the QR (Quick Response Rate) was measured based on the dispersion of response time for correct answers and performance at one level, more precisely, in our software, levels 1 and 4. Thus, it refers to the accuracy, consistency, and discernment with which the answers are given (Da Silva *et al.*, 2025).

Decision time (DT): This involves the process of selecting a response in an environment with multiple possible responses, inhibiting or guiding the touch action on the sensor according to the appropriate stimulus (Lezak *et al.*, 2012; Sanfey, 2007). The score will reflect the average decision time (in milliseconds) and the decision quality (DQ; 0 to 100), corresponding to the dispersion and accuracy of responses to stimuli in the go/no-go baseline task.

The DQ measurement was based on decision time, the sensitivity of detection of target stimuli compared to non-target stimuli, the dispersion of response time of correct responses, and performance at levels 2 and 3, which present more than one response option (Da Silva *et al.*, 2025). Furthermore, DT (in milliseconds) was calculated as the difference between the response time of correct responses at Level 3 (where there were two response options) and the reaction time.

Attention (AT): the ability to maintain focus on perceptual stimuli in the environment (Lopes Macedo *et al.*, 2019), is a cognitive function involved in the processes of activation and selection, distribution, and maintenance of psychological activity (Chun; Golomb; Turk-Browne, 2011; Greimel *et al.*, 2011). Its score (0 to 100) primarily reflects the participant's ability to omit errors and sustain this ability during the cognitive task. Thus, the calculation was based on the number of omissions, the dispersion of response time to correct answers, and the variations in performance in accuracy and response time between levels (Da Silva *et al.*, 2025).

Impulse control (IC): the ability to inhibit correct decisions (motor inhibition). The score (0 to 100) is based on the number of times the touch will occur without the presentation of an adequate stimulus for such a reaction, also considering the number of times the touch will occur in anticipation (before/less than 150ms) of the stimulus presentation. Thus, its calculation includes the number of commission errors, the number of anticipated responses, and the difference between the response times for correct responses and the response times for false signals (Da Silva *et al.*, 2025).

Peripheral vision (PV): comparison between the speed and accuracy of responses to stimuli presented in the peripheral positions of the visual field in relation to the speed and accuracy of responses to stimuli presented in the central positions (Sensorysports , [n.d.]).

2.8 Statistical analysis

The normality of the data was analyzed using the Shapiro-Wilk test. Continuous data were described as mean and standard deviation, and categorical data as percentages. Normal data were compared using the parametric t-test, and data that did not conform to normality were analyzed using the non-parametric Mann-Whitney test, both considering a 95% confidence interval (95% CI).

The normality of the data was analyzed using the Shapiro-Wilk test, and given the normality of the data, the t- test was used for all variables. Correlation tests between variables were also performed using Pearson's correlation coefficient for the intragroup normal distribution for each group. The effect size of the correlations was classified as very weak (< 0.20), weak (0.20–0.39), moderate (0.40–0.59), strong (0.60–0.79), and very strong (> 0.80) (Evans, 1996). The analyses were performed using Statistica 7 software.

3. RESULTS AND DISCUSSION

Twelve male BCR (Brazilian Cross-Country) athletes from the Brazilian national team were evaluated in Group 1 (G1), and 13 sedentary individuals in Group 2 (G2). Both groups were considered homogeneous in terms of demographic and anthropometric characteristics (p-value <0.05). However, heterogeneity was demonstrated in relation to the frequency of daily training sessions per week and the duration of each training session in hours. Information on the sample characteristics is presented in Table 1.

Table 1 - Characterization of the groups

	G1 (n = 12)	**G2 (n = 13)**	**p-value**
Variables	Mean ± SD	Mean ± SD	
Age (years)	33 ± 7.92	35.23 ± 9.70	0.537
Body mass (kg)	76 ± 18.85	86.38 ± 9.36	0.091
Height (m)	1.62 ± 0.39	1.74 ± 0.08	0.238
WB Time* (years)	11.3 ± 4.1	-	0.000
Training frequency (days/week)	4.91 ± 0.28	1.3 ± 1.97	0.000
Training duration (hours)	4.08 ± 0.90	0.38 ± 0.5	0.007
Variables	n (%)	n (%)	
Presence of visual impairment (all corrected)			
Yes	2 (16.6)	5 (38,46)	0.242
Preferred hand			
Left	2 (16.6)	1 (7.69)	
Right	10 (83.3)	12 (92.31)	

Source: author's own elaboration, 2025

The results obtained through the assessment of cognitive skills and emotional and mood factors using immersive VR are presented in Table 2. There was no statistically significant difference between the groups in any of the variables assessed.

Table 2 - Data obtained from the cognitive assessment and from emotional and mood factors

	G1 (n = 12)	**G2 (n = 13)**	**p-value**
Variables	Mean ± Standard deviation	Mean ± Standard deviation	
Cognitive domains			
Reaction time (milliseconds)	283 ± 31.63	272.92 ± 26.01	0.392
Decision time (milliseconds)	162.83 ± 65.49	163.7 ± 59.4	0.973
Attention (0 to 100)	54.83 ± 17.42	58.77 ± 18.78	0.593
Impulse control (0 to 100)	55.16 ± 17.26	60.3 ± 19.68	0.496
Variables	%	%	
Emotional factors and mood			
Mood level at the moment	79	64	0.155
Mood level at the moment	81	82	0.956
Sleep quality the previous night	80	80	0.748
Current voltage level	33	29	0.766

Source: author's own elaboration, 2025

In the correlation test between the cognitive variables of G1, TR demonstrated strong negative correlations with QR (r= -0.73), QD (r= -0.66) and AT (r= -0.66) and moderate negative correlations with VP (r= -0.53). In addition, QR showed moderate positive correlations with CI (r= 0.57) and VP (r= 0.50), while AT showed moderate positive correlations with QD (r= 0.55) and very strong correlations with VP (r= 0.81).

The results of the cognitive assessment were correlated with physical performance variables and internal factors (disposition, mood, sleep, and tension) for G1. Good mood showed moderate negative correlations with TD (r = -0.62) and positive correlations with CI (r = 0.62). The values obtained from the physical assessment of G1 are shown in Table 3. There was no statistically significant difference between the groups in any of the variables analyzed.

Table 3 - Results of the physical assessments of G1

	G1 (n = 12)
Variables	Mean ± Standard deviation
20-meter test	
Time from 0 to 5 meters (s)	1.96 ± 0.15
Acceleration (m/s²)	1.32 ± 0.20
Total time (s)	5.42 ± 0.40
Speed (m/s)	13.31 ± 0.96
YoYo Intermittent Endurance 1	
Maximum O2 consumption ($ml \cdot kg^{-1} \cdot min^{-1}$)	35.58 ± 3.86
Running Anaerobic Sprint Test	
Fatigue index (%)	-3.38 ± 2.24

Source: author's own elaboration, 2025

There were correlations between physical and cognitive levels between the AT variables and the 20-meter acceleration test, being negative and strong for the 0-5 meter time (r= -0.71) and total time (r= -0.70) and strong positive for acceleration (r= 0.66) and speed (r= 0.64).

This study aimed to evaluate the cognitive abilities of professional Paralympic basketball athletes compared to sedentary individuals and to compare these abilities with the physical performance of the athletes. Furthermore, it compared the cognitive domains of professional Paralympic basketball athletes and sedentary individuals with population reference values provided by the software. Although the results did not show statistically significant differences between groups, correlation analyses revealed relevant correlations between cognitive and physical variables, as well as the influence of emotional and mood factors on cognitive domains.

Given the importance of cognitive skills in athletic performance and the scarcity of assessment methods targeted at this population of BCR para-athletes, it is necessary to adopt precise and innovative analysis methods. In this context, VR instruments, through multiple sensory channels, make it possible to simulate user interactions with environments that resemble and are equivalent to real objects and events (Dellazizzo *et al.*, 2020; Zhang *et al.*, 2021).

Among its advantages, the ability to control environmental distractors and modify the difficulty of a task stands out. Given the latest technological advances, some VR systems have become low-cost and easy to use, promoting their adoption in clinical practice (Deblock-Bellamy *et al.*, 2021). However, previous studies that have used VR have focused their interests on developing and improving training methods and assessments of motor and cognitive performance in elderly populations or those with some pathology (Chen *et al.*, 2022; Galperin *et al.*, 2022; Mittal *et al.*, 2024; Ren *et al.*, 2024; Zhang *et al.*, 2021; Zhao *et al.*, 2022), not aiming to understand cognitive aspects of sports practice, especially in BCR para-athletes.

In our study, the correlation test between the cognitive variables of G1 indicated that the lower the RT, the better the scores in QR, QD, AT, and VP. Furthermore, it was demonstrated that the higher the QR, the better the CI and VP, and the more attentive the individuals were, the better the QD and VP. These findings suggest that cognitive variables are interdependent and that assessments of isolated cognitive abilities can infer an understanding of the others.

Thus, it contributes to the evidence that a large part of the hypothesized variables of executive functioning were strongly associated with reasoning skills and perceptual speed, these being interdependent variables that are also part of the cognitive domains, although they were not explored in this study. Therefore, VR is an alternative for those who do not have specialized instruments capable of measuring all the suggested skills (Salthouse, 2005).

Several factors are believed to contribute to improved cognitive performance, such as regular aerobic exercise (Pastor *et al.*, 2022; Stillman *et al.*, 2020), adequate nutrition (Dominguez *et al.*, 2021), and educational level (Lövdén *et al.*, 2020). Conversely, there is cognitive decline, which is characteristic of chronic neurodegenerative diseases (Dahmen *et al.*, 2017)and advancing age (Dominguez *et al.*, 2021). Investigations in the cognitive and athletic performance areas have revealed that expertise in sports is supported by perceptual and cognitive skills, as well as the ability to perform effective movement patterns (Hogan *et al.*, 2023). Similarly, a Scanlan *et al.* (2014)study reported that cognitive measures had a greater influence on reactive agility performance in male basketball players, also indicating a correlation between biomotor and cognitive domains.

Similarly, the present study showed that the shorter the time to cover the first 5 meters, the greater the acceleration, the shorter the total time to cover the distance, and the greater the speed, the higher the level of AT. That is, the better the AT of the BCR para-athlete, the better the performance in the 20-meter acceleration test, suggesting that cognitive performance may be correlated with physical performance.

Subtests of AT from more than half of the sample of child basketball players showed higher scores when compared to the normative sample, as seen in the work of [reference (Hogan *et al.* (2023)missing]. However, the present study did not find similar results for the population of BCR para-athletes, which may be partially attributed to the abnormal distribution of cognitive assessment data, characterized by extreme results, significantly above or below the group average.

Although there are results suggesting that assessment with probable stimuli, that is, those that allow for response preparation, are able to decrease the variability of RT, our study contradicts this finding, since it exposes visual stimuli randomly and rapidly, causing a greater need for AT, which can increase RT variability (Dankinas; Parciauskaite; Dapsys, 2015; Tam *et al.*, 2014).

In the present analysis, good mood was correlated with lower TD and better CI. Therefore, it was identified that internal factors, such as sleep (Henry *et al.*, 2019), mood, and tension, (Dion-Albert *et al.*, 2023)can influence cognitive performance. These findings are important because they confirm the correlations between emotional and mood factors and cognition, highlighting the importance of incorporating these variables when conducting cognitive assessment programs and intervention plans for athletic improvement.

According to existing literature, inhibitory control or motor inhibition is understood to be related to the inhibition of an incorrect response within a given context, and the opposite is called motor impulsivity (Bari; Kellermann; Studer, 2016; Patton; Stanford; Barratt, 1995). However (Lage *et al.*, 2011), impulsivity has been linked to motor control, with this relationship being more pronounced in slow execution conditions, given the greater need for control of attentional focus, contradicting our findings. This divergence may have been caused by methodological differences between the studies, the existence or absence of specific training aimed at developing these variables in the samples, the prior ability or inability of the individuals evaluated, among other factors.

In this study Mancı *et al.* (2023), trained basketball players demonstrated superior cognitive abilities compared to sedentary controls. Point guards showed superior visuospatial skills and short-term memory, while centers demonstrated superior visuospatial perception and timing ability, suggesting possible variability according to tactical position and partially explaining the variability in the data obtained.

Regarding the limitations of this study, we consider the insufficient number of wheelchair users who are not wheelchair users but are interested and available to participate in research as a control group. There was also no control for individuals familiar with the technology used.

4. FINAL CONSIDERATIONS

Based on the data obtained and discussed, no statistically significant differences were found between groups; however, within the group (G1), correlations were observed between cognitive and physical performance, as well as between psychophysiological conditions and cognitive performance.

REFERENCES

ADAMS, Jamie L. *et al.* Using a smartwatch and smartphone to assess early Parkinson's disease in the WATCH-PD study. **NPJ Parkinson's disease**, v. 9, n. 1, 1 dez. 2023.

BANGSBO, Jens; IAIA, F. Marcello; KRUSTRUP, Peter. The Yo-Yo intermittent recovery test: A useful tool for evaluation of physical performance in intermittent sports. **Sports Medicine**, v. 38, n. 1, p. 37–51, 2 out. 2008.

BARI, Andrea; KELLERMANN, Tanja S.; STUDER, Bettina. Impulsiveness and Inhibitory Mechanisms. **Neuroimaging Personality, Social Cognition, and Character**, p. 113–136, 1 jan. 2016.

CAMPBELL, Elizabeth; JONES, Graham. Cognitive Appraisal of Sources of Stress Experienced by Elite Male Wheelchair Basketball Players. **Adapted physical activity quarterly: APAQ**, v. 19, n. 1, p. 100–108, 2002.

CHEN, Xinming *et al.* Effects of Virtual Reality Rehabilitation Training on Cognitive Function and Activities of Daily Living of Patients With Poststroke Cognitive Impairment: A Systematic Review and Meta-Analysis. **Archives of Physical Medicine and Rehabilitation**, v. 103, n. 7, p. 1422–1435, 1 jul. 2022.

CHINNER, Amy *et al.* Digital technologies for the assessment of cognition: a clinical review. **Evidence-based mental health**, v. 21, n. 2, p. 67–71, 1 maio 2018.

CHUN, Marvin M.; GOLOMB, Julie D.; TURK-BROWNE, Nicholas B. A taxonomy of external and internal attention. **Annual review of psychology**, v. 62, p. 73–101, 10 jan. 2011.

DA SILVA, Carlos Mariano Aguiar Ferreira *et al.* Wheelchair skill tests in wheelchair Basketball: A systematic review. **PLOS ONE**, v. 17, n. 12, p. e0276946, 1 dez. 2022.

DA SILVA, Edilaine Aparecida *et al.* Effect of smartphone-based physical training combined with cognitive training on cognitive abilities in individuals with long COVID: A multicenter pilot randomized clinical trial. **Journal of Behavioral and Cognitive Therapy**, v. 35, n. 3, p. 100534, 1 ago. 2025.

DAHMEN, J. *et al.* **An analysis of a digital variant of the Trail Making Test using machine learning techniques**. Disponível em: <https://journals.sagepub.com/doi/abs/10.3233/THC-161274>. Acesso em: 22 abr. 2026.

DANKINAS, Denisas; PARCIAUSKAITE, Vykinta; DAPSYS, Kastytis. Intra-individual reaction time variability and response preparation: an EEG study. **Acta Neurobiologiae Experimentalis**, v. 75, n. 4, p. 462–468, 31 dez. 2015.

DEBLOCK-BELLAMY, Anne *et al.* Virtual reality-based assessment of cognitive-locomotor interference in healthy young adults. **Journal of neuroengineering and rehabilitation**, v. 18, n. 1, 1 dez. 2021.

DELLAZIZZO, Laura *et al.* Evidence on virtual reality-based therapies for psychiatric disorders: Meta-review of meta-analyses. **Journal of Medical Internet Research**, v. 22, n. 8, p. e20889, 1 ago. 2020.

DION-ALBERT, Laurence *et al.* Neurovascular adaptations modulating cognition, mood, and stress responses. **Trends in Neurosciences**, v. 46, n. 4, p. 276–292, 1 abr. 2023.

DOMINGUEZ, Ligia J. *et al.* Nutrition, Physical Activity, and Other Lifestyle Factors in the Prevention of Cognitive Decline and Dementia. **Nutrients 2021, Vol. 13, Page 4080**, v. 13, n. 11, p. 4080, 15 nov. 2021.

DRAPER, P. N.; WHYTE, G. **Anaerobic performance testing**. **University of Canterbury. School of Sport & Physical Education**University of Canterbury. School of Sport & Physical Education, 1997. Disponível em: <http://hdl.handle.net/10092/7835>. Acesso em: 4 fev. 2025

EVANS, James D. Straightforward statistics for the behavioral sciences. p. 600, 1996.

FALCK, Ryan S.; DAVIS, Jennifer C.; LIU-AMBROSE, Teresa. What is the association between sedentary behaviour and cognitive function? A systematic review. **British Journal of Sports Medicine**, v. 51, n. 10, p. 800–811, 1 maio 2016.

FANG, Kaiqin; JIANG, Han. Gender-Specific Effects of Short Sprint Interval Training on Aerobic and Anaerobic Capacities in Basketball Players: A Randomized Controlled Trial. **Journal of Sports Science & Medicine**, v. 23, n. 1, p. 8, 1 mar. 2024.

FOLSTEIN, Marshal F.; FOLSTEIN, Susan E.; MCHUGH, Paul R. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. **Journal of psychiatric research**, v. 12, n. 3, p. 189–198, 1975.

FREDRICKSON, J. *et al.* Evaluation of the usability of a brief computerized cognitive screening test in older people for epidemiological studies. **Neuroepidemiology**, v. 34, n. 2, p. 65–75, fev. 2010.

FREEMAN, D. *et al.* Virtual reality in the assessment, understanding, and treatment of mental health disorders. **Psychological Medicine**, v. 47, n. 14, p. 2393, 1 out. 2017.

GALPERIN, Irina *et al.* Treadmill training with virtual reality to enhance gait and cognitive function among people with multiple sclerosis: a randomized controlled trial. **Journal of Neurology 2022 270:3**, v. 270, n. 3, p. 1388–1401, 11 nov. 2022.

GAYA, Adroaldo; GAYA, Anelise. Manual de testes e avaliação. 2016.

GIL, Susana María *et al.* The Functional Classification and Field Test Performance in Wheelchair Basketball Players. **Journal of Human Kinetics**, v. 46, n. 1, p. 219, 1 jun. 2015.

GLATTKE, Kaycee E.; TUMMALA, Sailesh V.; CHHABRA, Anikar. Anterior Cruciate Ligament Reconstruction Recovery and Rehabilitation: A Systematic Review. **Journal of Bone and Joint Surgery**, v. 104, n. 8, p. 739–754, 20 abr. 2022.

GOROSTIAGA, Esteban M. *et al.* Differences in physical fitness among indoor and outdoor elite male soccer players. **European Journal of Applied Physiology**, v. 106, n. 4, p. 483–491, 26 mar. 2009.

GREIMEL, Ellen *et al.* Attentional performance in children and adolescents with tic disorder and co-occurring attention-deficit/hyperactivity disorder: new insights from a 2 × 2 factorial design study. **Journal of abnormal child psychology**, v. 39, n. 6, p. 819–828, ago. 2011.

HAFIZ, Pegah; BARDRAM, Jakob Eyvind. The Ubiquitous Cognitive Assessment Tool for Smartwatches: Design, Implementation, and Evaluation Study. **JMIR mHealth and uHealth**, v. 8, n. 6, 2020.

HENRY, Albert *et al.* The relationship between sleep duration, cognition and dementia: a Mendelian randomization study. **International Journal of Epidemiology**, v. 48, n. 3, p. 849–860, 1 jun. 2019.

HOGAN, Scott R. *et al.* The Athletic Intelligence Quotient and performance in the National Basketball Association. **Frontiers in Psychology**, v. 14, p. 1197190, 14 jul. 2023.

JIN, Roger; PILOZZI, Alexander; HUANG, Xudong. Current Cognition Tests, Potential Virtual Reality Applications, and Serious Games in Cognitive Assessment and Non-Pharmacological Therapy for Neurocognitive Disorders. **Journal of clinical medicine**, v. 9, n. 10, p. 1–19, 1 out. 2020.

KRUSTRUP, Peter *et al.* The Yo-Yo IR2 test: physiological response, reliability, and application to elite soccer. **Medicine and science in sports and exercise**, v. 38, n. 9, p. 1666–1673, set. 2006.

LAGE, Guilherme M. *et al.* Correlation between impulsivity dimensions and the control in a motor timing task. **Brazilian Journal of Motor Behavior**, v. 6, n. 3, p. 39–46, 27 nov. 2011.

LEZAK, Muriel Deutsch *et al.* Classes of Cognitive Functions. **Neuropsychological Assessment**, p. 25–37, 2012.

LOCKIE, Robert G. *et al.* The effects of different speed training protocols on sprint acceleration kinematics and muscle strength and power in field sport athletes. **Journal of Strength and Conditioning Research**, v. 26, n. 6, p. 1539–1550, jun. 2012.

LOPES MACEDO, Thuane *et al.* Analysis of the cognitive aspects of elderly people considering the practice of regular physical exercises and associated factors. **Revista Brasileira de Geriatria e Gerontologia**, v. 22, n. 2, p. e180120, 2019.

LÖVDÉN, Martin *et al.* Education and Cognitive Functioning Across the Life Span. **Psychological Science in the Public Interest**, v. 21, n. 1, p. 6–41, 1 ago. 2020.

MANCI, Egemen *et al.* The Effect of the Playing Positions in Basketball on Measures of Cognitive Performance. **Journal of Cognitive Enhancement 2023 7:3**, v. 7, n. 3, p. 230–241, 17 jun. 2023.

MARTIN, Jeffrey J. Multidimensional self-efficacy and affect in wheelchair basketball players. **Adapted physical activity quarterly: APAQ**, v. 25, n. 4, p. 275–288, 2008.

MILLMAN, L. S. Merritt *et al.* Towards a neurocognitive approach to dance movement therapy for mental health: A systematic review. **Clinical psychology & psychotherapy**, v. 28, n. 1, p. 24–38, 1 jan. 2021.

MITTAL, Palka *et al.* Effect of immersive virtual reality-based training on cognitive, social, and emotional skills in children and adolescents with autism spectrum disorder: A meta-analysis of randomized controlled trials. **Research in Developmental Disabilities**, v. 151, p. 104771, 1 ago. 2024.

MOLINA-GALLEGO, Brígida *et al.* Neuropsychological Study in Patients with Spinal Cord Injuries. **Healthcare 2021, Vol. 9, Page 241**, v. 9, n. 3, p. 241, 24 fev. 2021.

NAJAFABADI, Mahboubeh Ghayour *et al.* Wheelchair basketball, health, competitive analysis, and performance advantage: a review of theory and evidence. **Journal of Exercise Rehabilitation**, v. 19, n. 4, p. 208, 2023.

PASTOR, Diego *et al.* Physical Exercise and Cognitive Function. **International Journal of Environmental Research and Public Health 2022, Vol. 19, Page 9564**, v. 19, n. 15, p. 9564, 3 ago. 2022.

PATTON, J. H.; STANFORD, M. S.; BARRATT, E. S. **Factor structure of the Barratt impulsiveness scale - PubMed**. Disponível em: <https://pubmed.ncbi.nlm.nih.gov/8778124/>. Acesso em: 22 abr. 2026.

PROESP-BR. **Bateria de Testes: Velocidade de Deslocamento (corrida de 20 metros)**. Disponível em: <https://www.ufrgs.br/proesp/bat-teste-velocidade-de-deslocamento.php>. Acesso em: 4 fev. 2025.

RAVAGNANI, Christianne de Faria Coelho; BORGES, Dayanne Sarah Lima; DOS REIS, Caroline Rezende. Avaliação multiprofissional do atleta. **Universidade Federal do Mato Grosso do Sul**, 2022.

REN, Yuanyuan *et al.* Effects of immersive and non-immersive virtual reality-based rehabilitation training on cognition, motor function, and daily functioning in patients with mild cognitive impairment or dementia: A systematic review and meta-analysis. **Clinical Rehabilitation**, v. 38, n. 3, p. 305–321, 1 mar. 2024.

SALTHOUSE, Timothy A. Relations between cognitive abilities and measures of executive functioning. **Neuropsychology**, v. 19, n. 4, p. 532–545, jul. 2005.

SANFEY, Alan G. Decision neuroscience: New directions in studies of judgment and decision making. **Current Directions in Psychological Science**, v. 16, n. 3, p. 151–155, jun. 2007.

SCANLAN, Aaron *et al.* The influence of physical and cognitive factors on reactive agility performance in men basketball players. **Journal of Sports Sciences**, v. 32, n. 4, p. 367–374, 2014.

SENSORIALSPORTS. **NeuroSports Arena: a única arena para o treinamento cerebral de atletasbile**. Disponível em: <https://sensorialsports.com/neurosports-arena/>. Acesso em: 9 jan. 2024.

SILVA, Carlos Mariano Aguiar Ferreira da *et al.* Does Mental Fatigue Affect Physical Performance in Wheelchair Basketball Players? An Individualized Cognitive Load Approach. **Perceptual and motor skills**, v. 132, n. 5, p. 1108–1128, 1 out. 2025.

STILLMAN, Chelsea M. *et al.* Effects of Exercise on Brain and Cognition Across Age Groups and Health States. **Trends in Neurosciences**, v. 43, n. 7, p. 533–543, 1 jul. 2020.

TAM, Angela *et al.* Effects of reaction time variability and age on brain activity during Stroop task performance. **Brain Imaging and Behavior 2014 9:3**, v. 9, n. 3, p. 609–618, 4 out. 2014.

VAN ROYEN, Annelies *et al.* Go or no-go? An assessment of inhibitory control training using the GO/NO-GO task in adolescents. **Appetite**, v. 179, 1 dez. 2022.

WEBER, Vinícius M. R. *et al.* Adaptation of Anaerobic Field-Based Tests for Wheelchair Basketball Athletes. **Research Quarterly for Exercise and Sport**, v. 92, n. 4, p. 715–722, 2 out. 2021.

WIEBE, Annika *et al.* Virtual reality in the diagnostic and therapy for mental disorders: A systematic review. **Clinical psychology review**, v. 98, 1 dez. 2022.

ZAGATTO, Alessandro M.; BECK, Wladimir R.; GOBATTO, Claudio A. Validity of the running anaerobic sprint test for assessing anaerobic power and predicting short-distance performances. **Journal of strength and conditioning research**, v. 23, n. 6, p. 1820–1827, set. 2009.

ZHANG, Qi *et al.* Impact of virtual reality-based therapies on cognition and mental health of stroke patients: Systematic review and meta-analysis. **Journal of Medical Internet Research**, v. 23, n. 11, p. e31007, 1 nov. 2021.

ZHAO, Junqiang *et al.* Virtual reality technology enhances the cognitive and social communication of children with autism spectrum disorder. **Frontiers in Public Health**, v. 10, p. 1029392, 6 out. 2022.

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