Examining the ability to track multiple moving targets as a function of postural stability: A comparison between team sports players and sedentary individuals (#74148)

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Examining the ability to track multiple moving targets as a function of postural stability: A comparison between team sports players and sedentary individuals

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Background. The ability to track multiple objects plays a key role in team ball sports actions. However, there is a lack of research focused on identifying multiple object tracking (MOT) performance under rapid, dynamic and ecologically valid conditions. Therefore, we aimed to assess the effects of manipulating postural stability on MOT performance.

Methods. Nineteen team sports players (soccer, basketball, handball) and sixteen sedentary individuals performed the MOT task under three levels of postural stability (high, medium, and low). For the MOT task, participants had to track three out of eight balls for 10 seconds, and the object speed was adjusted following a staircase procedure. For postural stability manipulation, participants performed three identical protocols (randomized order) of the MOT task while standing on an unstable platform, using the training module of the Biodex Balance System SD at levels 12 (high-stability), 8 (medium-stability), and 4 (low-stability).

Results. We found that the ability to track moving targets is dependent on the balance stability conditions ($F_{2,66} = 8.7$, $p < 0.001$, $\eta^2 = 0.09$), with the disturbance of postural stability having a negative effect on MOT performance. Moreover, when compared to sedentary individuals, team sports players showed better MOT scores for the high-stability and the medium-stability conditions (corrected p-value = 0.008, Cohen´s d = 0.96 and corrected p-value = 0.009, Cohen´s d = 0.94; respectively) whereas no differences were observed for the more unstable conditions (low-stability) between-groups.

Conclusions. The ability to track moving targets is sensitive to the level of postural stability, with the disturbance of balance having a negative effect on MOT performance. Our results suggest that expertise in team sports training is transferred to non-specific sport domains, as shown by the better performance exhibited by team sports players in comparison to sedentary individuals. This study provides novel insights into the link between individual’s ability to track multiple moving objects and postural control in team sports players and sedentary individuals.

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Abstract

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Introduction

In the highly dynamic and constantly changing scenario of team sports such as basketball, soccer or handball, athletes need to rapidly process a considerable amount of information in order to make appropriate decisions (Ashford et al. 2021; Roca & Williams 2016). In this regard, the ability to track moving objects seems to be a crucial aspect of perceptual-cognitive function towards skilled performance in different sport disciplines (Howard et al. 2018; Mackenzie et al. 2021).

The multiple object tracking (MOT) test, which is based on the manipulation of spatiotemporal demands, has been developed to evaluate and enhance the ability to track targets within a dynamic environment where all objects are in constant motion (Pylyshyn & Storm, 1988). In team sports, there is scientific evidence showing that the speed of tracking multiple objects is positively associated with sport expertise in soccer (Faubert 2013) ~~and~~ rugby (Harris et al. 2020), and basketball (Jin et al. 2020; Qiu et al. 2018). Indeed, MOT performance has demonstrated to be associated with specific measures of game performance (assists, turnovers, assist-to-turnover ratio, steals) in professional basketball players (Mangine et al., 2014). Interestingly, a laboratory MOT training intervention improved passing decision-making in soccer players (Romeas et al., 2016) and enhanced processing speed and sustained attention in volleyball players (Fleddermann et al. 2019). Moreover, the ability to track moving targets seems to be associated with sport performance, and also, its improvement could have a positive impact on applied contexts.

In real game situations, a number of targets are in constant motion (i.e., the opponent, teammates, the ball), and it usually occurs while players' moving. Indeed, team sports are characterized by the repeated combination of high-intensity actions such as sprints, jumps, accelerations, decelerations and multiple changes-of-direction, interspersed with brief low-intensity periods of running and standing (Bishop & Girard 2013). To maintain the integrity of the sport-specific skills, team sports have a greater demand on coupling the athlete's perceptual-cognitive and motor subsystems (Davids et al. 2001; Farrow & Abernethy 2003). This integrity between higher perceptual-cognitive function and the player's motor system has been confirmed by the analysis of effective motor behaviors in skilled athletes, as for example in soccer dribbling (Fransen et al. 2017), agility tasks performance (Spiteri et al. 2018), and defensive actions in soccer (Roca et al. 2011). In addition, dynamic balance is defined as the ability to control the postural stability during complex movements and challenging postural conditions (e.g., during external mechanical perturbations) (Paillard & Noé 2015). Regarding team sports, dynamic balance is considered as a functional prerequisite to perform complex motor skills such as ball control (Paillard 2017) or agility tasks (Stirling et al. 2018). In this context, it seems appropriate to consider the bidirectional relationship between the motor and perceptual-cognitive functions in more realistic scenarios, namely when stability is compromised. In our opinion, a lack of perception-movement coupling in research contexts is failing to replicate sport-specific situations, and thus, there is a ~~lack of knowledge in this matter~~.

Based on the previously reported research gaps, the aim of the present study was to assess the impact of manipulating the level of postural stability on MOT performance in a sample of team sports players and sedentary individuals. In this study, participants performed the MOT task under three levels of postural stability using the Biodex Balance System (Biodex Medical Systems Inc, Shirley, New York, USA). It is expected that MOT performance would be positively associated with the level of stability since visual search performance has been linked to stability (Marsh et al. 2010). Also, it is hypothesized that athletes, when compared to non-athletes, would achieve greater MOT scores (Howard et al. 2018; Qiu et al. 2018) and have better dynamic postural control (Reynard et al. 2019), resulting in a better MOT performance with different levels of stability.

Materials & Methods

Participants

An a-priori sample size calculation was performed using G*Power 3.1 (Faul et al., 2007), assuming an effect size of 0.25, alpha of 0.05, and power of 0.85. This analysis projected a minimum sample size of 32 participants (16 participants in each group) for the desired statistical power. A total of 35 males were included in this study, 19 professional and semiprofessional team sports players (soccer: n = 6; basketball: n = 7; and handball: n = 6) and 16 university students, who did not regularly practice physical activity (see **Table 1** for a description of the experimental sample). All participants had no history of major lower limb injury and were free of any visual deficit. All participants were informed about the testing procedure, and signed a written informed consent. This study was approved by the University of Granada´s Institutional Review Board (IRB approval: 1180/CEIH/2020).

Postural stability assessment

Participants were tested individually, and all assessments were conducted in the same room under constant environmental conditions. Initially, the bilateral static and dynamic postural stability tests were carried out by using the Biodex Balance System SD (Biodex Medical Systems Inc, Shirley, New York, USA). Postural stability tests were performed on static (rigid surface setting) and dynamic platforms (multiaxial platform with 12 levels of instability, maximum tilt of 20 degrees). Test duration for each of the two balance tasks was 80 seconds (three trials of 20 seconds each, with a rest interval of 10 seconds between each). The dynamic postural stability test was performed with platform stability on levels 8 to 4. For all trials, participants were tested barefoot. During testing, participants looked straight ahead to a reference point with their arms folded along their chest. The overall stability index (OSI) (°), the anterior-posterior stability index (APSI) (°), and the medial-lateral stability index (MLSI) (°) were determined. Higher scores of stability index indicate poorer postural stability.

Multiple object tracking (MOT)

Following previously described procedures for the MOT test (see **Figure 1, panel C**), eight identical black balls (diameter 2.06º) were projected on a 65 cm white square background with a luminance of 107 cd/m2, which subtended a visual angle of 36°, using a 55-inches television monitor (Samsung, UE55NU7172, Korea) placed at 1 m. Three of these balls were randomly illuminated in green for 2 seconds before returning to the baseline black color. The participant was instructed to track these three balls for 10 seconds. The examiner did not give any specific instruction about how performing the task (eye movements were allowed). All balls moved randomly following a linear path and a constant speed and step size. The balls only deviated from a smooth path when they collided against another ball or the walls. After 10 seconds, all the balls were frozen in place and a number, from 1 to 8, was assigned to each one. The participant was asked to identify the three balls that were originally illuminated based on their location in the display (Fehd & Seiffert, 2008). The speed of the balls was adjusted with a 1-up 1-down staircase procedure, increasing the speed if the participant correctly identified all three balls or decreasing the speed if at least one ball identified incorrectly (Levitt, 1971). The initial speed of the balls was set at 26.3 cm/s, and after each correct or incorrect response the speed was increased or decreased by 0.05 log, respectively. The staircase stopped after six reversals, and the threshold was estimated by the mean of the speeds of the last four reversals.

Procedure

To complete the MOT task, each participant performed three testing conditions (three levels of stability) in a randomized manner with a rest interval of 10 minutes between two consecutive conditions. During the execution of the MOT task, participants tried to keep balance on an unstable platform working at the training module of the Biodex Balance System SD. Each testing session was different with levels of platform stability, (i.e., level 12 [high stability with maximum platform tilt of 1.7°], level 8 [medium stability with maximum platform tilt of 8.4°] and level 4 [low stability with maximum platform tilt of 15.0°]). An experienced examiner gave standardized instructions and monitored the testing procedure. All assessments had a standardized familiarization protocol, which included two MOT trials using the initial speed (26.3 cm/s). **Figure 1** depicts a graphical illustration of the testing procedure.

Statistical analyses

Descriptive data are presented as means and standard deviations. The normal distribution of the data (Shapiro-Wilk test) and the homogeneity of variances (Levene´s test) were confirmed ($p > 0.05$). In order to determine the possible differences between team sports players and sedentary individuals for OSI, APSI, and MLSI, three separate t-tests for independent samples were carried out. For the main analysis, a mixed ANOVA with "stability level" as the only within-participants factor, and "group" as the only between-participants factor, was performed for MOT score. The possible associations between stability indexes (OSI, APSI, and MLSI) in static and dynamic conditions with MOT scores were assessed by separate linear regression analyses. A p-value of 0.05 was considered to determine statistical significance, and the magnitude of the differences (effect sizes) were reported using the Cohen´s d (d´) and eta squared (η^2) for t- and F-tests, respectively. The criteria for interpreting the magnitude of the effect sizes were: trivial (<0.2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2.0) and extremely large (>2.0) for Cohen´s d (Hopkins et al. 2009) and small (0.01), medium (0.06), and large (0.14) for eta squared (Cohen 1988). Post-hoc comparisons were corrected by the Holm-Bonferroni procedure, and the JASP statistical package (version 16.1) was used for all analyses.

Results

Descriptive and statistical values for static and dynamic OSI, APSI, and MLSI in the groups of team sports players and sedentary individuals are shown in **Table 2**.

In the static postural balance task, team sports players did not statistically differ from sedentary individuals in terms of stability indexes (p-values > 0.05, Cohen´s ds ranging from 0.073 to 0.297). Similarly, in the dynamic postural balance task, there were no statistically significant differences between both experimental groups (p-values > 0.05, Cohen´s ds ranging from 0.035 to 0.240).

For the analysis of MOT performance, the main effects of "stability level" ($F_{2,66} = 8.7$, $p < 0.001$, $\eta^2 = 0.09$) and "group" ($F_{1,33} = 10.9$, $p = 0.002$, $\eta^2 = 0.15$) reached statistical significance, but the interaction "stability level" × "group" was not statistically significant ($F_{2,66} = 1.9$, $p = 0.678$, $\eta^2 = 0.01$) (**Figure 2**). Regarding stability level, greater MOT scores were found for the high-stability in comparison to the medium-stability (corrected p-value < 0.001, Cohen´s d = 0.67) and low-stability (corrected p-value = 0.005, Cohen´s d = 0.54) conditions. However, the comparison between the medium-stability and low-stability conditions did not reveal statistically significant differences (corrected p-value = 0.444, Cohen´s d = 0.13). Statistically significant post-hoc comparisons between both experimental groups for each stability level are depicted in **Figure 2**.

The analysis of the association between stability indices and changes in MOT performance across conditions showed that either static and dynamic postural balance were not correlated with MOT performance. However, there were positive correlations between sports experience and MOT scores in the high-stability (r = 0.414, p = 0.013) and medium- stability (r = 0.365, p = 0.031) conditions (**Figure 3**).

Discussion

We examined the effects of manipulating postural stability on the ability to track moving objects in team sports players and sedentary individuals. Our main findings are that, when compared to sedentary individuals, team sports players showed better MOT scores for the high-stability and medium-stability conditions whereas no between-groups differences were reached in the more unstable conditions (low-stability). Also, a negative association was found between MOT performance and the stability level, showing that the ability to track moving targets is dependent on the stability conditions.

Our results are in line with previous studies showing that the ability to track moving targets is of special relevance in dynamic sports, and thus, expertise from the sport domain characterized by dynamically changing, high-paced and unpredictable scenario may transfer to a more general perceptual-cognitive domain (i.e., MOT) (Faubert 2013; Harris et al. 2020; Howard et al. 2018; Jin et al. 2020; Qiu et al. 2018). Electrophysiological evidence suggests that the effects of regular sport training cause improvements in the sensory stage of information processing (Zwierko et al. 2014), as well as the decision making stage (Sharhidd Taliep et al. 2008). Specifically, Qiu et al. (2019) reported that the neural efficiency of better MOT performance in team sport athletes is associated with bidirectional reductions in cortical activation and deactivation. In fact, these authors found that during the execution of a MOT task, athletes demonstrated less activation in attention-related brain areas and less deactivation in the medial superior frontal gyrus in comparison to non-athletes. Taken together, the results of this study corroborate that team sports players have a greater ability to track moving targets than individuals who do not regularly practice physical activity.

Our findings suggest that the advantage of athletes over non-athletes in MOT scores may result mainly from perceptual-cognitive expertise and enhanced ability to perception-action coupling, rather than a better postural control. Somewhat surprisingly, the initial scores of dynamic overall stability index indicated non-statistically significant differences between groups, with the magnitude of the differences being negligible to small (Cohen´s d s $\leq$ 0.240). Although, it is widely accepted that postural performance is improved after regular sport activity (Reynard et al. 2019), it is also known that in experienced athletes the postural balance adaptation is very specific to the context of the sport practice, therefore an effect of its transfer to non-specific contexts is modest or inexistent (Paillard 2017). Moreover, morphological parameters of athletes, such is a higher body height, may also have some influence on the postural stability test results. Indeed, body height is recognized as the anthropometric variable with greater influence on postural balance (Alonso et al. 2012), which may partially explain the current results (p-value = 0.099 for the height differences between groups).

Despite the differences in MOT performance between team sports players and sedentary individuals, the changes in MOT scores under increasing postural instability was similar in both experimental groups. In other words, the ability to track moving objects was modulated as a function of postural stability regardless of sport experience. Given the complexity of the task used (i.e., MOT in unstable conditions) in this investigation, the integration of multiple sensory inputs and the coordination of multiple motor outputs is required. The results obtained may be explained by the uncoupling of the perceptual-cognitive and motor systems as result of the disturbance caused by compromising postural balance (Vidal & Lacquaniti 2021). Moreover, in challenging spatiotemporal conditions, attention narrows to goal-directed orientation (i.e. objects' tracking), limiting the cognitive/motor processing linked to keep balance on an unstable platform (Abernethy 1993). This "competition" for attention negatively affects the motor control system, resulting in a dysfunction of the perceptual-cognitive and motor flow integrity (Tenenbaum & Land 2009). Of note, the cognition-action interaction in the domain of visual attention involves arousal processes (Davranche & Audiffren 2004), but also, inhibitory control processes play a role in this activity (Tiego et al. 2018). Recently, Park et al. (2021) examined the impact of performing physical effort (handgrip exertion) at two intensity levels on visual search. They found a faster behavioral performance with physical effort due to the arousing effects of handgrip exertion, however, the most physically demanding condition caused a heightened interference from the singleton distractor and impaired cognitive performance as consequence of the reduced inhibitory control. Moreover, perceptual-cognitive skills seem to be highly dependent on the specific context of assessment, as corroborated by the manipulation of the stability conditions in the current study.

It is also plausible to hypothesize that changes in MOT performance results during the increasing instability of the platform were caused by oculomotor system disturbances. During the execution of the MOT task, the observer is required to maintain its fixation, specifically when the center-looking strategy (attending to all the targets as a group) is used (Fehd & Seiffert 2008), which consequently causes the inhibition of eye movements (Howe et al. 2009). On the contrary, postural balance in dynamic conditions is controlled by the use of saccadic eye movements or smooth pursuit movements which, in contrary to fixation, attenuate postural sway (Rodrigues et al. 2015; Zwierko et al. 2020). The issue of oculomotor coordination when performing tasks with concomitant demands of different nature worth being investigated. Future research should try to ~~determine~~ the eye movement strategies that lead to successful tracking of moving objects in unstable conditions.

The current results provide novel insights into the relationship between the ability to track multiple moving targets and the level of postural stability. However this study is not exempt of limitations and they must be acknowledged. First, our experimental sample was formed by athletes from three sport disciplines (i.e., soccer, basketball, and handball). There is scientific evidence that the ability of attentional control in MOT tasks varies across sport disciplines (Harris et al. 2020), and even across representatives of the same sport discipline as an effect of playing position on the court (Mangine et al. 2014; Martín et al. 2017). Second, previous studies have shown a gender-effect on the ability to track multiple objects (Roudaia & Faubert 2017) and thus, the level of association between the MOT task and dynamic postural stability could differ between men and women. Therefore, our results need to be cautiously interpreted in this regard (i.e., sport discipline/expertise and gender). Third, while the current findings support the potential utility of including MOT for team sport training, further studies examining the relationship between MOT performance in ecological contexts (e.g., under dynamic conditions) and game-related performance are needed.

Conclusions

Our data exhibit that team sports players have a better ability to track multiple moving targets under different levels of postural stability than sedentary individuals. Based on the present findings, it seems reasonable to state that expertise in team sports training, integrating the perceptual-cognitive and movement processes, is transferred to non-specific sport domains. The ability to track moving targets is sensitive to the postural stability level, with the disturbance of postural stability having a negative effect on MOT performance. These findings provide novel insights into the link between individual's ability to track multiple moving objects and postural control in team sports players and sedentary individuals.

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Figure legends

Figure 1. A graphical illustration of the testing procedure A) starting position where the participant was standing on an unstable platform working at the training module of the Biodex Balance System SD placed 1 m in front of the television monitor; B) three levels of platform stability: high (level 12), medium (level 8) and low (level 4); C) four stages of the MOT task, i.e. presentation stage where three out of eight targets (balls) were temporarily (2 s) highlighted on green color; movement stage where the targets were at the same color (black) and all moved for 10 seconds crossing and bouncing each other; identification stage where the targets were frozen and marked with numbers, and the participant had to identify by giving three numbers of balls originally highlighted in the presentation stage; feedback stage where the participant was given information of the correct targets.

Figure 2. Boxplot of the effect of stability conditions on multiple objects tracking performance in a group of team sports players (in red) and sedentary individuals (in blue). Statistically significant differences are depicted in the figure (Holm-Bonferroni corrected p-value < 0.05), and the magnitude of the differences are reported by Cohen´s d. The box plots represent 75th, 50th and 25th centiles. Horizontal lines and circles into the box represent median and mean values, respectively. The whiskers show the standard deviation.

Figure 3. Heat map showing separate linear regression analyses between the different variables assessed in this study. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 1

A graphical illustration of the testing procedure

A) starting position where the participant was standing on an unstable platform working at the training module of the Biodex Balance System SD placed 1 m in front of the television monitor; B) three levels of platform stability: high (level 12), medium (level 8) and low (level 4); C) four stages of the MOT task, i.e. presentation stage where three out of eight targets (balls) were temporarily (2 s) highlighted on green color; movement stage where the targets were at the same color (black) and all moved for 10 seconds crossing and bouncing each other; identification stage where the targets were frozen and marked with numbers, and the participant had to identify by giving three numbers of balls originally highlighted in the presentation stage; feedback stage where the participant was given information of the correct targets.

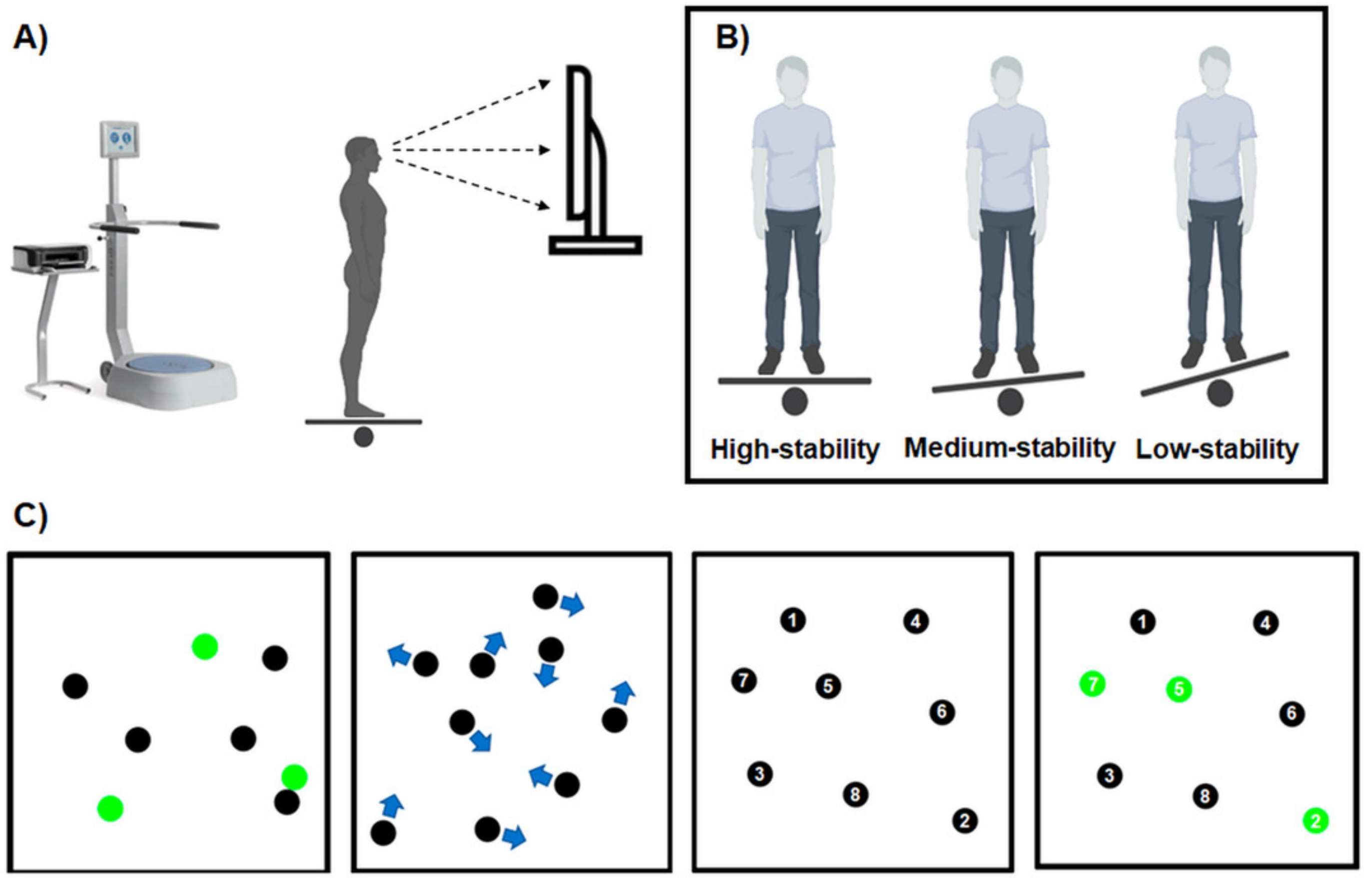
A)
B)
High-stability
Medium-stability
Low-stability
C)
1
4
7
5
6
3
8
2

Figure 2

Boxplot of the effect of stability conditions on multiple objects tracking performance in a group of team sports players (in red) and sedentary individuals (in blue).

Statistically significant differences are depicted in the figure (Holm-Bonferroni corrected p-value < 0.05), and the magnitude of the differences are reported by Cohen´s d. The box plots represent 75th, 50th and 25th centiles. Horizontal lines and circles into the box represent median and mean values, respectively. The whiskers show the standard deviation.

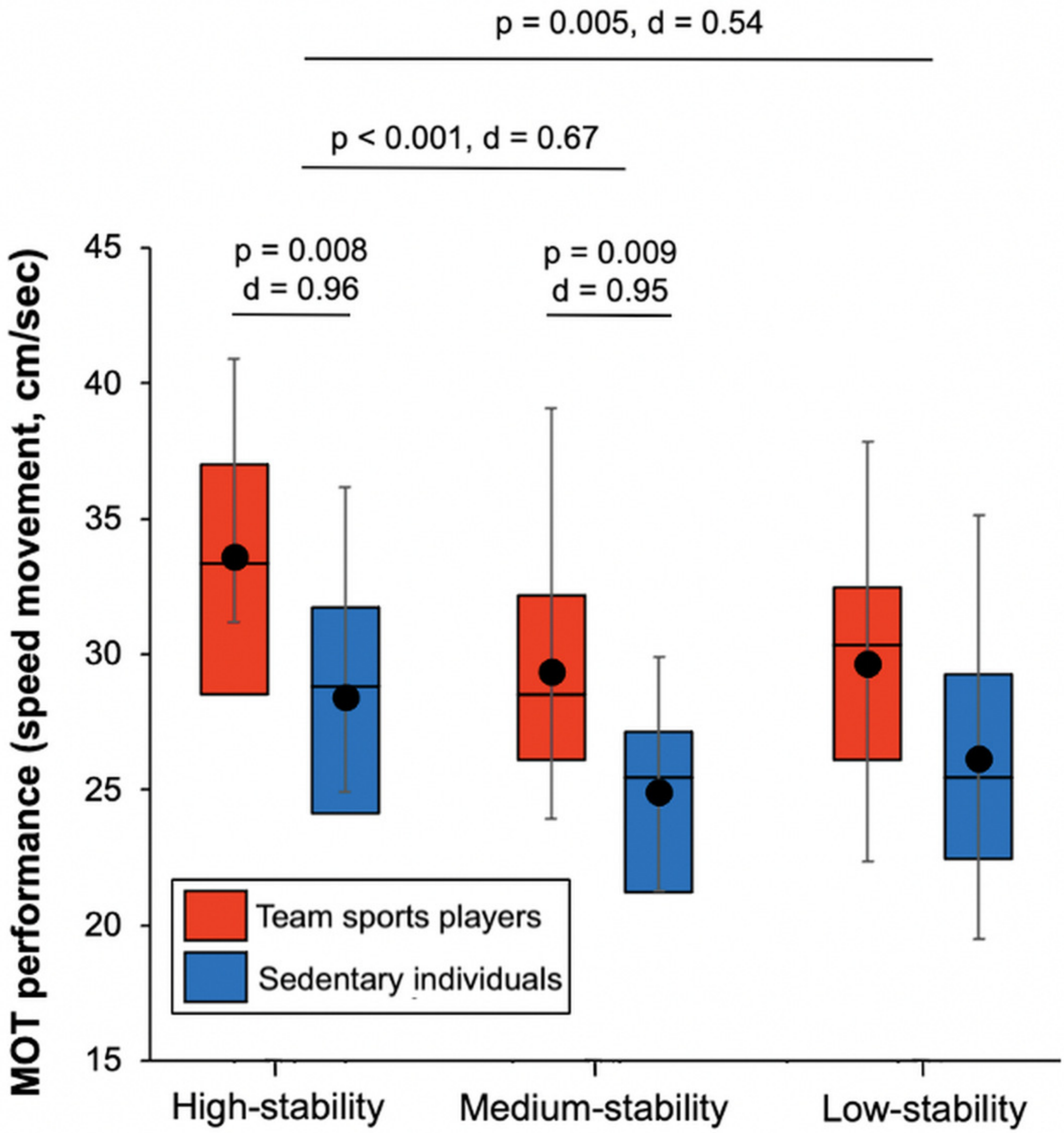
p = 0.005, d = 0.54
p < 0.001, d = 0.67
p = 0.008
d = 0.96
p = 0.009
d = 0.95
MOT performance (speed movement, cm/sec)
45
40
35
30
25
20
15
Team sports players
Sedentary individuals
High-stability
Medium-stability
Low-stability

Figure 3

Heat map showing separate linear regression analyses between the different variables assessed in this study.

*p < 0.05, ** p < 0.01, *** p < 0.001

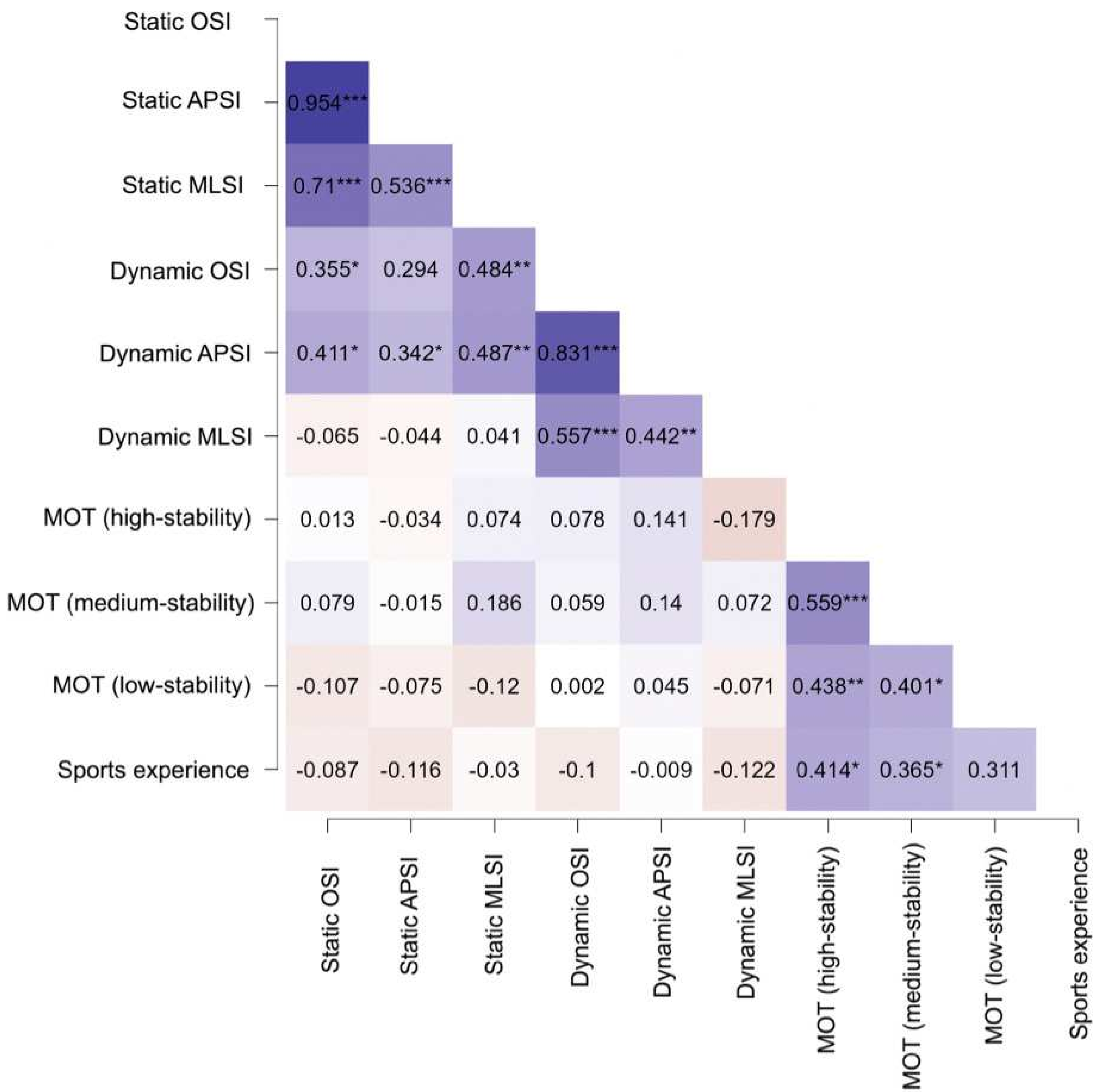

Table 1 (on next page)

Descriptive (mean ± standard deviation) characteristics of the experimental sample, and its statistical comparison between groups.

Table 1. Descriptive (mean ± standard deviation) characteristics of the experimental sample, and its statistical comparison between groups.

	Team sports players (n =19)	Sedentary individuals (n = 16)	p-value
Age (years)	20.7 ± 2.6	19.7 ± 2.0	0.222
Height (cm)	188.1 ± 8.0	183.9 ± 6.2	0.099
Weight (Kg)	82.2 ± 12.0	78.3 ± 9.5	0.301

Table 2 (on next page)

Descriptive and statistical values for static and dynamic OSI, APSI, and MLSI in the groups of team sports players and sedentary individuals.

Note: OSI- overall stability index, APSI- anterior-posterior stability index, MLSI- medial-lateral stability index

Table 2. Descriptive and statistical values for static and dynamic OSI, APSI, and MLSI in the groups of team sports players and sedentary individuals.

Postural balance	Stability index	Team sports players	Sedentary individuals	p-value (Cohen's d)
Static	**OSI** (°)	0.311 ± 0.221	0.369 ± 0.260	0.479 (0.243)
	APSI (°)	0.216 ± 0.201	0.275 ± 0.198	0.388 (0.297)
	MLSI (°)	0.153 ± 0.077	0.163 ± 0.182	0.831 (0.073)
Dynamic	**OSI** (°)	0.884 ± 0.257	0.956 ± 0.346	0.485 (0.240)
	APSI (°)	0.658 ± 0.295	0.669 ± 0.336	0.920 (0.035)
	MLSI (°)	0.526 ± 0.268	0.569 ± 0.265	0.642 (0.159)

Note: OSI- overall stability index, APSI- anterior-posterior stability index, MLSI- medial-lateral stability index