v. 2, n. 43, 2022

International Journal of Health Science

RELATIONSHIP BETWEEN STATIC BALANCE, DYNAMIC BALANCE AND CHANGE OF DIRECTION MOVEMENTS IN HEALTHY YOUNG INDIVIDUALS

Caruline Rodrigues Alvarenga
0000-0003-4567-1660

Vinícius Saura Cardoso
0000-0003-0269-7473

Abstract: Background: With postural stability, the body is capable of performing functions directed to the performance of a task. Directional movements are examples of function that require balance to be effective. The relationship between functional capacities assists to understand the transfer of skills, and for that, it is important to gather information about the relationship between postural balance and movements of change of direction. Hypothesis: First, healthy young individuals do not show relation between their functional capacities for static postural stability and dynamics. Second, there is a relationship between dynamic stability and movements of change of direction, based on motor learning between tasks performed under functional capacities involving voluntary motor acts. Methods: 32 healthy men performed tests of static balance, dynamic balance, and performance in change of direction movements. Spearman correlations were made with the stabilometric variables of the Center of Pressure (CoP) oscillation, mean of the distances (cm) of excursion, the simplified SEBT test, time (ms) of completion of movements of changes of direction, in the Y-shaped test. Results: Random correlations between the CoP variables and the directions of the simplified SEBT, not characterizing a significant relationship, suggesting that they are specific tasks, given the requirement for different perceptual skills. Significant correlations between the directions of the SEBT and movements of change of direction, mainly for planned configuration, justified by the similarity of response to the demands of the movement, a voluntary motor action. In reactive directional movements, other perceptual skills are required for better performance, the relationship with dynamic balance is not exclusive. Conclusions: There is no relationship between static and dynamic balance in healthy young people, however, there is a relationship between dynamic balance and planned change of direction movements.

Keywords: Dynamic balance; learning; motor skills; reaction time; static balance.

INTRODUCTION

Postural stability is a fundamental skill for daily life (Duarte, Freitas, 2010), with which the body may be able to perform a function, directed to the performance of a behavioral task (Shumway-Cook, Woollacott, 2010). As the plasticity of postural function adjusts to acquire the ability to maintain stable balance and restore postural stability after a motor action, the neuromotor system offers conditions for other, more demanding actions that have new goals (Latash, 2018; Profeta, Truvey, 2018; Shumway-Cook, Woollacott, 2010; Scholz, Schoner, 1999).

Static balance is the ability to remain in a posture, minimizing the effects of gravitational forces, and keeping the body within the bounds of the support base. This ability underlies any voluntary movement, which requires stability to be (Shumway-Cook, Woollacott, 2010; Scholz, Schoner, 1999). In dynamic equilibrium, regulatory adjustments are made in response to postural disturbances caused by the motor act, so that a function can be performed stably (Bouisset, 2008).

As the maturation of the motion control processes takes place, providing conditions for automatic and organized movements acquired over the properties of repetitive stimuli, multiple interactions act to acquire new motor actions, which require conscious processes capable of provoking anticipatory judgments in tasks that require decision making (Abernethy et al, 2012; Jackson, Farrow, 2005; Beek, 2000). An example is the change of direction movements, which consist of performing a rapid deceleration before a rapid acceleration in a new direction voluntarily (Young, Dawson, Henry, 2015).

Change of direction movements is a function that promotes mobility, being an extremely useful motor act for locomotion and sports (Lockie et al, 2016). It is also a task that changes in response to random external stimuli, for which it requires fast and accurate perceptual and decision-making skills (Lockie et al, 2016; Young, Dawson, Henry, 2015; Serpell, Young, Ford, 2011). Recent data suggest that exposure to a variety of motor learning paradigms may enable individuals to acquire general and transferable skills among other skills, promoting more strategic movement regulation alternatives (Reschechtko, Zatziorsky, Latash, 2017; Lefumat et al, 2015; Mussgens, Ullen, 2015). Other authors state that these specific skills are acquired faster through exposure to environmental demands and similar movements (Giboin, Gruber, Kramer, 2019; D'Avella, 2016; Seidler, 2004).

The purpose of this study was to verify the relationship of dependence and the degree of association between static balance, dynamic balance and change of direction movements tasks in healthy individuals. For this, the variables were acquired by instrumented stabilometry (Duarte, Freitas, 2010) (static balance), the simplified Star Excursion Balance Test (SEBT) (Kinzey, Armstrong, 1998) (dynamic balance), and the Y-shaped test for change of directions movements (Oliver, Meyers, 2009).

The first hypothesis of this study predicts that healthy young individuals, after achieving static stability and consequent automation of the control path of this posture, do not show dependence between their functional capacities of static postural stability and the dynamics, considering the requirement of distinct and consequent perceptive abilities different motor control solutions. The second hypothesis is the existence of the relationship between dynamic stability and movements of change of direction based on motor learning between tasks performed under similar functional capacities involving voluntary motor acts.

METHODS

The research receiving favorable opinion from the local ethics committee (nº Opinion: 2.174.266). Male volunteers, aged 17 to 27 years, healthy, non-alcoholics, non-smokers were admitted. Individuals with known vestibular disorders were excluded; who underwent surgery within 1 year of data collection; who had known neuromuscular disorders; who underwent major lower limb surgery; who took continuous medications or were under acute treatment; and who were in inflammatory and/or infectious processes.

All subjects accepted the consent form and responded to an initial assessment of physical and anthropometric conditions. They were then instructed on the tests to which they were submitted, performed on different days, or alternatively subjected to static balance evaluation before dynamic balance and change of direction evaluation.

STATIC BALANCE ASSESSMENT

Subjects were positioned on the EMG System® force platform, staring at a point marked at eye level and one meter in front of them, with their upper limbs crossed and resting on their shoulders, with their feet positioned in parallel, at a distance of 10 cm between them. The foot position was marked on the platform and reproduced in all static balance tests: bipodal eyes opened support (BEO), bipodal eyes closened support (BEC), unipodal eyes opened support (UEO), unipodal eyes closened support (UEC), performed in this sequence (Figure 1). The bipodalic and unipodalic tests lasted 125 and 25 seconds, respectively (Gao et al, 2011).

Static posturography analyzed the CoP coordinates under the requested tasks in the time-space, spectral and structural domains. To obtain this information, the software Biomec400 (EMG System of Brazil®) was used, calibrated for a signal acquisition frequency of 100Hz and amplifier gain of 600 times. For the analysis of the results, we used Matlab® Version R2013a and MS-Excel® 2010 in the preparation of the collected variables.

The variables found for analysis were: CoP displacement area (AREA) (cm2); greater stability area (STABAREA) (cm^2); range of displacement in the anteroposterior and midlateral directions (RANGE) (cm); average oscillation speed in both directions (mV) (cm/s); the variability of the CoP displacement from its mean position over a time interval (RMS); median frequency or at 50% of spectral power (F50) (Hz); frequency at 80% of spectral power (F80) (Hz), both in each direction, anteroposterior and midlateral; sample entropy for the anteroposterior and midlateral directions (SENT); and cross entropy (CROSSENT).

Figure 1 – Image representing the partipant´s positioning on the time of data collection. Legend: (A) Bipodal; (B) Unipodal. Source: Author (2018)

DYNAMIC STATIC ASSESSMENT

The simplified Star Excursion Balance Test (SEBT) was performed with participants standing in the middle of a grid consisting of eight lines that extend 45° apart (Figure 2A). For each participant was asked get as far as possible along three directions (anterior, posteromedial and posterolateral) and lightly touch the line with the most distal part of the evaluated limb, without allowing contact to affect the support, returning the reach leg to the center, while maintaining a single leg posture with the other leg in the center of the grid (Gribble et al, 2013). Five attempts were made for each limb in each direction (anterior, posteromedial, and posterolateral) (Figure 2B).

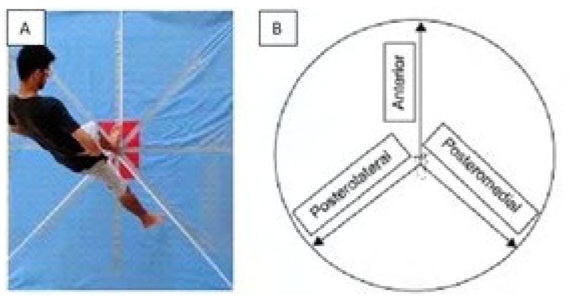

Figure 2 – Simplified Star Excursion Balance Test (SEBT). Legend: (A) Grid simplified SEBT; (B) Directions used in the assessment (example of the right member).

The terminology of excursion directions is based on the direction of reach in relation to the supporting leg. For example, when reaching in the posterolateral direction, participants must reach behind the supporting leg laterally to complete the task (Gribble, Hertel, Plisky, 2012).

The evaluator recorded each reach attempt as the distance from the center of the grid to the maximum excursion point for the reach leg, using a standard tape measure for each attempt. If the evaluator felt that the participant used the reach leg with a substantial amount of support or removed his

International Journal of Health Science ISSN 2764-0159 DOI 10.22533/at.ed.1592432201085

foot from the center of the grid or could not maintain balance on the support leg during the attempt, the test would be discarded and repeated.

The distances were normalized through the equation below (Gribble et al, 2013):

DISTANCE normalized = (ATTEMPT verified/ LIMB LENGTH) X 100

Individually, the average in centimeters (cm) of each direction was considered. Then averaged only including directions.

CHANGE OF DIRECTIONS MOVEMENTS ASSESSMENT

For the planned and reactive Y-shaped test, each individual performed 10-minute warm-ups prior to the experimental protocol tests. Subjects started all sprints from a position 30 cm behind the first timing gate (figure 3).

Movement times (from the beginning of subjects' response to an exit gate) were recorded by video decomposition performed on open-source Windows software (CvMob® 3.6). The cutoff for the beginning were with the activation of fluorescent light, ending the test with the passage of the point marked on the alba line through the exit gate. The exit gates were placed at the left and right end of the test course, and the center point of each gate is visually placed perpendicularly 45° to the intended running line.

The directions were indicated by directive arrows left or right, presented by a monitor positioned in front of the participant. Subjects completed a series of planned sprints and another series of reactive sprints. Each series contained two right and two left sprints, all rotating at the midpoint marked on the course.

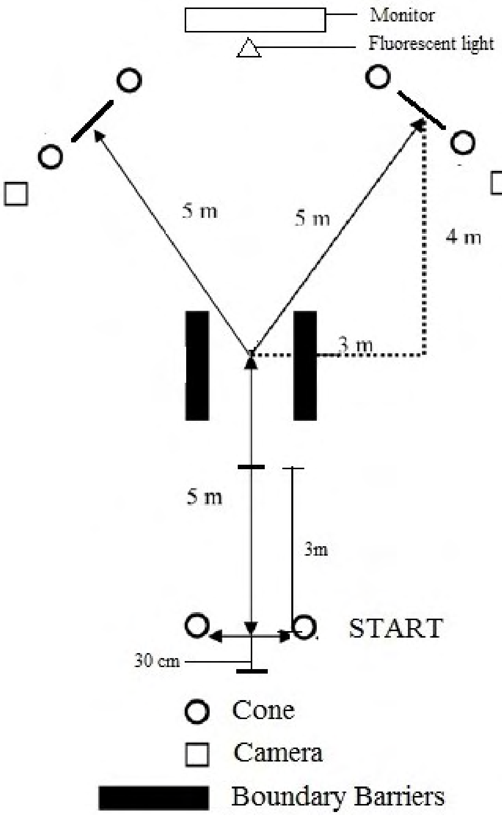

Figure 3 – Experimental Diagram of Y-shaped change of direction test. Modified from Oliver and Meyers (2009).

For the reactive configuration assays, the directions were randomly triggered and presented by the monitor. After the volunteers started sprinting, when they crossed the 3m mark, the direction was then revealed and individuals were forced to react to this stimulus and run as quickly as possible through the exit gate (Oliver, Meyers, 2009). During reactive turn-around sprints, participants were instructed not to try to predict which exit port they were required to go through. To ensure that this did not happen, the evaluator visually monitored the technique.

Individually, we considered an average of the times traveled in the planned configuration, and another average in the reactive configuration, in milliseconds (ms).

STATISTICAL ANALYSIS

Descriptive statistics were made to establish the sample profile. Data normality was verified by the Shapiro-Wilk test. Spearman rank order correlation (rs) were executed in the evaluation of the variables between static and dynamic balance, and between dynamic balance and the change of direction test. The following correlation magnitudes were considered between the variables: negligible - below 0.3; low - 0.31-0.5; moderate - 0.51-0.7; strong - 0.71-0.9; and very strong - above 0.9 (Mukaka, 2012). For data analysis, SPSS for Windows version 20.0 was used, considering p <0.05 as significant.

RESULTS

32 healthy young males, with an average age of 20.81 ± 2.47 years, an average weight of 69.37 ± 11.02 kg, an average height of 174.20 ± 7.44 cm, made up the sample.

There were few correlations between the variables in the static and dynamic balance assessments (table 1). In the BEO trial, there was a correlation between mVap and the anterior direction of the SEBT (rs = 0.390, p = 0.027). In the BEC trial, the F50ap showed a correlation with the posterolateral (rs = 0.438, p = 0.012) and posteromedial (rs = 0.418, p = 0.017) directions. In the UEO assay, the F50ap correlated with the posteromedial direction (rs = 0.373, p = 0.036). There was no significant correlation between the tests in the UEC assay and the assessment of dynamic equilibrium.

Analyzing the dynamic balance and direction change tests, there was a correlation between all SEBT test directions and the planned configuration (anterior direction, rs=

	Stabilometric Variables											
	BEO			BEC			UEO			UEC		
SEBT Directions	A	PL	PM	A	PL	PM	A	PL	PM	A	PL	PM
AREA (cm^2)	0,285	-0,075	0	-0,071	-0,022	-0,047	0,285	-0,133	-0,037	-0,184	-0,197	-0,12
STABAREA (cm^2)	0,317	-0,007	0,04	-0,028	0,096	0,08	0,249	-0,093	0	-0,154	-0,199	-0,103
$RANGE_{ap}$ (cm)	0,228	-0,027	-0,034	-0,121	0,104	0,038	0,243	-0,234	-0,056	-0,178	-0,177	-0,109
$RANGE_{ml}$ (cm)	0,155	-0,032	-0,009	-0,012	0,015	0,118	0,226	0,063	-0,092	-0,002	-0,204	-0,098
mV_{ap} (cm/s)	0,390*	0,196	0,229	0,174	0,128	0,097	0,168	-0,095	0,096	-0,12	-0,307	0,018
mV_{ml} (cm/s)	0,137	0,008	0,062	0,11	0,01	-0,021	0,162	0,163	0,161	-0,085	-0,174	-0,043
RMS_{ap}	0,251	-0,052	-0,023	-0,01	-0,008	-0,053	0,212	-0,284	-0,113	-0,152	-0,215	-0,175
RMS_{ml}	0,234	-0,117	-0,046	-0,065	-0,049	-0,103	0,21	0,098	-0,011	-0,19	-0,192	-0,131
$F50_{ap}$ (Hz)	-0,038	0,056	-0,098	0,292	0,438*	0,418*	0,068	0,034	-0,049	0,333	-0,032	-0,373*
$F80_{ap}$ (Hz)	-0,051	0,169	0,073	0,261	0,279	0,269	-0,117	-0,005	0,044	0,145	-0,078	0,334
$F50_{ml}$ (Hz)	-0,073	0,203	0,117	0,053	0,152	0,066	0,037	0,135	0,151	0,148	-0,004	-0,209
$F80_{ml}$ (Hz)	-0,119	0,117	0,108	-0,008	0,01	0,061	0,06	0,031	0,173	-0,013	-0,017	0,229
$SENT_{ap}$	-0,05	0,239	0,202	0,036	0,118	0,079	-0,037	0,138	0,124	0,09	-0,156	0,234
$SENT_{ml}$	-0,135	0,098	0,038	0,081	0,01	0,003	-0,054	0,103	0,191	0,103	-0,091	0,04
CROSSENT	-0,253	0,059	0,008	0,08	0,018	0,023	-0,066	0,338	0,343	0,206	0,207	0,225

Legend: BEO- bipodal support with eyes opened; BEC- bipodal support with eyes closed; UEO- unipodal support with eyes opened; UEC- unipodal support with eyes closed; A- Direction Anterior; PL – Direction Posterolateral; PM- Direction Posteromedial. *p<0.05

Table 1 – Spearman rank correlation coefficients between the results of the static equilibrium evaluation stabilometric variables in the BEO, BEC, UEO and UEC tests, and the distances reached in the proposed directions of the Star Excursion Balance Test (SEBT) test (n=32).

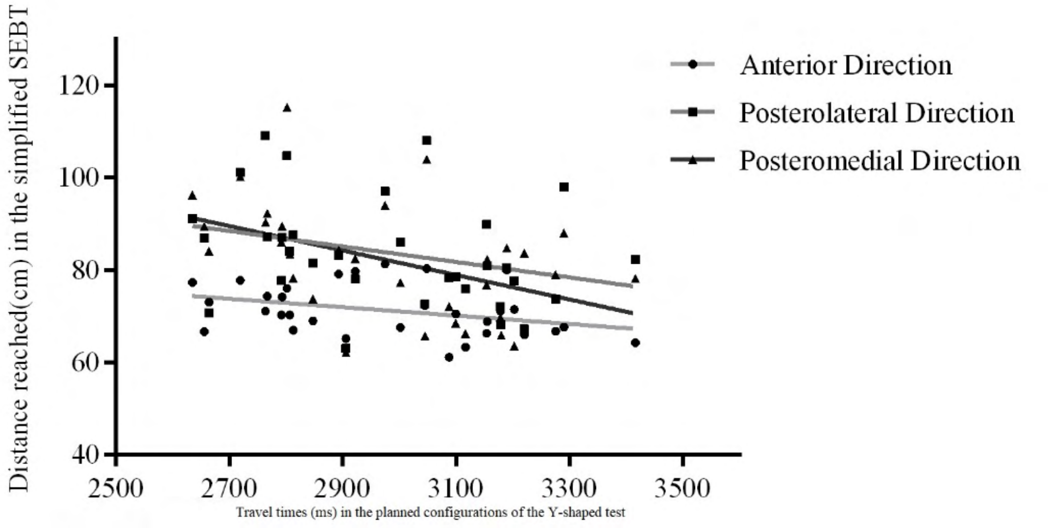

Figure 4 - Correlation of Sperman's order (rs) between the distances reached from the directions of the simplified Star Excursion Balance Test (SEBT) and the travel times in the planned configurations of the Y-shaped test (n = 32) (p < 0.05).

-0,362, p = 0,041; posterolateral, rs = - 0,380, p = 0,032; posteromedial, rs = - 0,507, p = 0,003). With the reactive configuration, there was significant correlation with the posteromedial direction (rs = -0,372, p = 0.036). There was no significant correlation between the reactive configuration and the anterior (rs = -0.190) and posterior (rs = -0.279) directions (figure 4).

DISCUSSION

This study aimed to verify the relationship between static balance, dynamic balance and change of direction tasks, in order to gather information on learning skills. Therefore, the individuals had their performances investigated about the correlation among themselves.

The relationships between the static and dynamic balance tasks performed in this study showed almost no correlation (table 1). In general, the static balance and dynamic balance test parameters did not result in a significant relationship. Therefore, the first hypothesis of this study is true.

In general principles, the central nervous system integrates the sensorimotor systems continuously, organizing the neuromuscular entry and exit, through the peripheral receptors, to activate the postural muscles in order to maintain an upright posture or to recover balance after external disturbances or challenging postures.

The variables found in stabilometry recorded CoP over time, indexes frequently used to make inferences about postural stability. These variables measure part of the body's oscillation characteristics, making it necessary to use them under different domains (Duarte, Freitas, 2010; Scholz, Schoner, 1999). By the space-time domain, the stabilometric variables define structural characteristics of the oscillation displacement. Variables under the frequency domain define important characteristics commonly associated with the principles of postural control, and can describe the energy levels contained in the unique frequencies that make up the CoP. And then, the analyzes under the structural domain were proposed to analyze the complexity of the signal, and to quantify the unpredictability of the CoP's oscillation over time, evaluating the probability that specific values will occur within the signal, considering the similarities (Gao et al, 2011; Duarte, Freitas, 2010; Scholz, Schoner, 1999).

In this study, postures with different difficulties of static balance were used to investigate the variables of CoP oscillation, including performing them with eyes open and with eyes closed. This distinction was based on the idea that inhibition of sensory input from vision for postural control could cause temporary changes in the rearrangements of muscle activations, resulting in greater oscillations of the signal (Duarte, Freitas, 2010; Scholz, Schoner, 1999). Since, with more challenging postures for postural control, the variables would indicate adaptive differences for the organization of the sensory interaction of each individual.

Static balance is considerate a skill organized under automatic control characteristics to become efficient (Duarte, Freitas, 2010), influenced under biological maturation processes (Hrysomalis, McLaughlin, Goodman, 2006) and considered as a general skill (Karimi, Solomonidis, 2011). In this study, the dynamic stability evaluated by the SEBT excursions is an adaptive function with voluntary movements that are influences by environmental demands, requiring conscious processes of reaction to the sensorimotor processes, not automated and adapted to each situation (Giboin, Gruber, Kramer, 2019).

The literature suggests that the variable practice of some skill is advantageous to influence a general task, but does not interfere with specific tasks (D'Avella, 2016; Hrysomalis, McLaughlin, Goodman, 2006). They also add that the differences found in task stimulus responses may be the result of differences in exposure to motor learning (D'Avella, 2016).

For this study, it is not knowledge to us that the task performed by the SEBT, which evaluated the dynamic balance, had not yet been related to the variables of the static balance instrumented stabilometry. However, since dynamic balance has been evaluated by other instruments, these findings are in agreement with previous studies (John et al, 2019; Kiss, Schedler, Muehlbauer, 2018; Steinberg et al, 2017; Pau et al, 2015), in which they report weak associations or no correlation between static balance and dynamic balance in men. A recent review (Krakauer, Mazzoni, 2011) included 26 studies that related the performance of static and dynamic balance tasks in healthy individuals, quantifying the correlations between them, and indicate that these tasks appear to be specific.

The relationships between SEBT excursions and the time taken to perform the planned change of directions movements (figure 4) in this study showed correlations, especially with the planned configuration. The anterior and posterolateral directions of the SEBT presented a weak negative correlation with the planned configuration, and the posteromedial direction showed a moderate correlation with the planned configuration of the Y-shaped test, where, as the distances reached were longer, Y-shaped test path was shorter. These findings indicate a relationship of dependence between dynamic balance and planned change of directions movements, where the more functional capacity for dynamic balance is attained, the faster to perform planned changes of direction.

Lockie et al (2016) had already suggested the existence of a relationship between dynamic stability measured by SEBT functional range and planned change of direction in athletes through other tests of change of direction. Rouisse et al (2018) recently presented a multiple regression analysis in which dynamic balance performance explained between

20% and 75% of the variance of the planned change of directions tests. These studies suggest that relationships possibly occurred due to similarities in movement demands and muscle recruitment (Rouisse et al, 2018; Lockie et al, 2016).

For the reactive configuration of the Y-shaped test, the relationship was weak, and only with the posteromedial SEBT direction, which is reported to be the best for predicting dynamic functional capabilities for the test 9Hertel et al, 2006). In reactive change of direction, movement control occurs with greater involvement and dependence on perceptual processes (Serpell, Young, Ford, 2011), in which the best learning conditions are susceptible to specific tasks and contexts (Nimphius et al, 2018; Roca, Williams, 2017; Abernethy et al, 2012), and the components involving physical abilities make less contributions to this task (Young, Dawson, Henry, 2015).

Based on our findings the second hypothesis of this study was considerate partially true. This is because the findings demonstrate strong relationships only to the planned configuration of the Y-shaped test. Thus, as the individual has better dynamic balance, the better will be the performance on the planned change of directions movements and the reactive configuration of the Y-shaped test, the dependence on dynamic balance is smaller.

Motor control theories emphasize that the motor system does not remain stationary, and the maintenance of organism functioning is varying between situations (Scholz, Schoner, 2018; Roca, Williams, 2017; Shumway-Cook, Woollacott, 2010). In motor learning, after adapting to sensory impressions acquired through tasks that involve conscious and voluntary processes, such as dynamic balance (Roca, Williams, 2017; Bouisset, 2008), the ability to respond to the demands of the task becomes more adequate (Jackson, Farrow, 2005), and is more likely to be transferred to other functions, also volunteers (D'Avella, 2016; Lefumat et al, 2015; Mussgens, Ullen, 2015; Davids et al, 2003).

CONCLUSIONS

Static balance and dynamic balance performances are unrelated to healthy young men. For this study, the dynamic balance evaluated by the SEBT and planned change of directions movements evaluated by the Y-shaped test were strongly related, but the dynamic stability and the reactive configuration did not.

REFERENCES

ABERNETHY B, SCHORER J, JACKSON R, HAGEMANN N. Perceptual training methods compared: The relative efficacy of different approaches to enhancing sport-specific anticipation. **Journal of Experimental Psychology: Applied**. 2012; 18(2):143-153.

BEEK PJ. Toward a theory of implicit learning in the perceptual-motor domain. **International Journal of Sport Psychology.** 2000; 31(4): 547–554.

BOUISSET S. Posture, dynamic stability and voluntary movement. **Clinical Neurophysiology.** 2008; 38: 345-362.

D´AVELLA A. Modularity for motor control and motor learning. **Advances in Experimental Medicine and Biology.** 2016; 957: 3-19.

DAVIDS K, GLAZIER P, ARAUJO D, BARTLETT R. Movement Systems as dynamical systems: the functional role os variability and its implications for sports medicine. **Sports Medicine**. 2003; 33 (4): 245-260.

DUARTE M, FREITAS SMSE. Revisão sobre posturografia baseada em plataforma de força para avaliação do equilíbrio. **Revista Brasileira de Fisioterapia.** 2010; 14(3): 183-92.

GAO J *et al*. Shannon and Renyi Entropies to Classify Effects of Mild Traumatic Brain Injury on Postural Sway. **PLoS ONE.** 2011; 6(9): e24446.

GIBOIN L, GRUBER M, KRAMER A. Motor learning of a dynamic balance task: Influence of lower limb power and prior balance practice. **Journal of Science and Medicine in Sport.** 2019; 22(1): 101-105.

GRIBBLE PA, HERTEL J, PLISKY P. Using the star excursion balance test to assess dynamic postural-control deficits and outcomes in lower extremity injury: A literature and systematic review. **Journal of Athletic Training.** 2012; 47(3): 339-357.

GRIBBLE PA, KELLY S, REFSHAUGE K, HILLER C. Interrater reliability of the Star Excursion Balance Test. **Journal of Athletic Training**. 2013; 48(5): 621-626.

HERTEL J, BRAHAM RA, HALE SA, OLMSTED-KRAMER LC. Simplifying the star excursion balance test: analyses of subjects with and without chronic ankle instability. **Journal of Orthopaedic and Sports Physical Therapy**. 2006; 36(3): 131-7.

HRYSOMALIS C, MCLAUGHLIN P, GOODMAN C. Relationship between static and dynamic balance tests among elite Australian Footballers. **Journal of Science and Medicine in Sport**. 2006; 9: 288-291.

JACKSON RC, FARROW D. Implicit perceptual training: How, when, and why? **Human Movement Science**, 2005; 24: 308–325.

JOHN C, RAHLF AL, HAMACHER D, ZECH A. Influence of biological maturity on static and dynamic postural control among male youth soccer players. **Gait and Posture.** 2019; 68: 18-22.

KARIMI MT, SOLOMONIDIS S. The relationship between parameters of static and dynamic stability tests. **Journal of Research in Medical Sciences**. 2011; 16(4): 530–535.

KINZEY S, ARMSTRONG C. The Reliability of the Star-Excursion Test in Assessing Dynamic Balance. **Journal of Orthopaedic & Sports Physical Therapy.** 1998; 27(5): 356-360.

KISS R, SCHEDLER S, MUEHLBAUER T. Associations Between Types of Balance Performance in Healthy Individuals Across the Lifespan: A Systematic Review and Meta-Analysis. **Frontiers in Physiology**. 2018; 9: 1-11.

KRAKAUER J, MAZZONI P. Human sensorimotor learning: Adaptation, skill, and beyond. **Current Opinion in Neurobiology**. 2011; 21(4): 636-644.

LATASH, ML. Abundant Degrees of Freedom Are Not a Problem. **Kinesiology Review.** 2018; 7(1): 64-72.

LEFUMAT HZ *et al*. To transfer or not to transfer? Kinematics and laterality quotient predict interlimb transfer of motor learning. **Journal of Neurophysiology.** 2015; 114(5):2764-2774.

LOCKIE RG, CALLAGHAN SJ, JEFFRIESS MD, LUCKO J. Dynamic stability as measured by time to stabilization does not relate to change-of-direction speed. **Physical Education and Sport**, 2016; 14(2): 179-191.

MUKAKA MM. Statistics Corner: A guide to appropriate use of Correlation coefficient in medical research. **Malawi Medical Journal.** 2012; 24(3): 69-71.

MÜSSGENS DM, ULLEN F. Transfer in Motor Sequence Learning: Effects of Practice Schedule and Sequence Context. **Frontiers in Human Neuroscience**. 2015; 24(9).

NIMPHIUS S, CALLAGHAN SJ, BEZODIS NE, LOCKIE R. Change of Direction and Agility Tests: Challenging Our Current Measures of Performance. **Strength and Conditioning Journal**. 2018; 40(1): 26-30.

OLIVER JL, MEYERS RW. Reliability and Generality of Measures of Acceleration, Planned Agility, and Reactive Agility. **International Journal of Sports Physiology and Performance.** 2009; 4(3): 345- 354.

PAU *et al*. Relationship Between Static and Dynamic Balance Abilities in Italian Professional and Youth League Soccer Players. **Physical Therapy in Sport**. 2015; 16(3): 236-241.

PROFETA VLS, TRUVEY MT. Bernstein's levels of movement construction: A contemporary perspective. **Human Movement Science.** 2018; 57: 111-133.

RESCHECHTKO S, ZATZIORSKY VM, LATASH ML. The synergic control of multi-finger force production: stability of explicit and implicit task components. **Experimental Brain Research**. 2017; 235(1): 1-14.

ROCA A, WILLIAMS AM. Does decision making transfer across similar and dissimilar sports? **Psychology of Sport and Exercise**. 2017; 31: 40-43.

ROUISSI M *et al*. Implication of dynamic balance in change of direction performance in young elite soccer players is angle dependent? **The Journal of Sports Medicine and Physical Fitness.** 2018; 58(4): 442-449.

SCHOLZ J, SCHONER G. The uncontrolled manifold concept: Identifying control variables for a functional task. **Experimental Brain Research.** 1999; 126(3): 289-306.

SEIDLER RD. Multiple motor learning experiences enhance motor adaptability. **Journal of Cognitive Neuroscience**. 2004; 16(1): 65–73.

SERPELL BG, YOUNG WB, FORD M. Are the perceptual and decision-making Components of agility trainable? A Preliminary investigation. **The Journal of Strength and Conditioning Research.** 2011; 25(5):1240-48.

SHUMWAY-COOK A, WOOLLACOTT MH. **Controle Motor. Teoria e aplicações práticas**. 3 ed. São Paulo: Manole; 2010.

STEINBERG N, ADAMS R, WADDINGTON G, KARIN J, TIROSH O. Is There a Correlation Between Static and Dynamic Postural Balance Among Young Male and Female Dancers? **Journal of Motor Behavior**. 2017; 49(2).

YOUNG WB, DAWSON B, HENRY GJ. Agility and Change-of-Direction Speed are Independent Skills: Implications for Training for Agility in Invasion Sports. **International Journal of Sports Science & Coaching**. 2015; 10(1): 159-69.