SOCIETY. INTEGRATION. EDUCATION
Proceedings of the International Scientific Conference. Volume VI, May 22th -23th, 2020. 312-323

THE EFFECTS OF COGNITION AND FUNCTIONAL PERFORMANCE ON CORE STABILITY IN THE ELDERLY POPULATION: A CROSS-SECTIONAL STUDY

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Abstract. *The researches indicate that core stability may play a substantial role in reducing fall risk in the elders. Nevertheless, cognition and functional performance has been identified with fall risks as well. The impact of functional performance elements and/or cognition on core stability, to complement the intervention programs for seniors in the future, has not been fully studied. This study aimed to assess the effects of leg strength, static balance, walking speed and cognition on the core stability scores. In a cross-sectional design study a sample of 62 participants were eligible for the study. Elderly aged 60 or older living in Social care centers or autonomous were recruited. Independent variables included static balance, walking speed, leg strength measured by Short Physical Performance Battery, cognition (alertness, divided attention, selective attention, and working memory) evaluated with the Rehacom screening software and age. Dependent variable core stability (the ability to maintain appropriate contraction of muscle transversus abdominis) was assessed performing Prone test with Chattanooga Stabilizer Pressure Biofeedback. A hierarchical multiple regression was used for statistical analysis. Static balance and cognition presented greater effects significantly explaining 18% and 13% of the variability of core stability, whereas no significant effects of walking speed and leg strength were found on core stability. Exercise programs where static balance and cognition tasks are implemented to complement core stability performance might be worth investigating and compare with other intervention methods to reduce the risk of falling in the elderly population.*

Keywords: *accidental falls, aging, cognition, physical functional performance, transversus abdominis.*

http://dx.doi.org/10.17770/sie2020vol6.5189

Introduction

Aging is a process that can consequently result in deterioration of a person's functional state, which could lead to an augmented incidence of falls (Granacher, Gollhofer, Hortobagyi, Kressig, & Muehlbauer, 2013) therefore affecting daily activities. There has been evidence stating that daily activities are dependent on both sensorimotor processes and higher-level cognitive functions (Laessoe, Hoeck, Simonsen, & Voigt, 2008). It is known the (pre)frontal lobe (associated with executive function (Yuan & Raz, 2014)) is vulnerable to age-related degeneration (Fjell, McEvoy, Holland, Dale, & Walhovd, 2014; Fjell et al., 2009; Pfefferbaum et al., 2013; Raz, 1999; N. Raz et al., 1997) and it has been established that sensorimotor training where core is controlled by supraspinal centers or cognitive functions may be more efficacious than customary training programs (Markovic, Sarabon, Greblo, & Krizanic, 2015).

Furthermore, the components as muscle mass, bone density and neural system also are affected by degeneration processes (Granacher et al., 2013). The studies recommend that exercise methods challenging muscle endurance, strength and balance would improve scores of functional performance in seniors (Cadore, Rodriguez-Manas, Sinclair, & Izquierdo, 2013). The scores of functional performance are supposedly influenced by core performance as well (Granacher et al., 2013). Even though, it appears that the core may play a substantial role in controlling sensorimotor processes during everyday activities (Granacher et al., 2013), the opposite neural pathways controlled by functional performance have not been fully researched. Functionally, the core is challenged by external and internal forces and it must manage the transfer of torques and angular moments between the hands and legs while maintaining body equilibrium (Behm, Drinkwater, Willardson, & Cowley, 2010), therefore functional performance and supraspinal activation skills may play substantial role during these challenges. The core stability that can be defined as the ability to maintain or resume an equilibrium position of the trunk after perturbation (Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007) is based on three subsystems: the passive spinal column, active spinal muscles and a neural control unit (Panjabi, 1992). It is suggested that the central nervous system uses contraction of the transversus abdominis (TrA) to stabilize the lower spine, in anticipation of activation of the prime movers of the limbs (Hodges & Richardson, 1996).

While the association between the trunk muscle strength and functional performance (e.g. static balance, walking speed and leg strength) has been described (Baker et al., 2007; Suri, Kiely, Leveille, Frontera, & Bean, 2009), the impact of functional performance elements and cognition on core stability has not been fully studied in older adults. Based on the evidence stating that the importance of voluntary control over the trunk muscles is crucial for maintaining static or dynamic balance (Anderson & Behm, 2005; Haefeli, Vögeli, Michel, & Dietz, 2010) and that there is lack of evidence examining the functional performance on core we aim to describe the effects of leg strength, cognition, static balance, gait speed on the core stability scores and hypothesize that functional performance and cognition could influence core stability.

Methods

The study was based on a cross-sectional design. Between May 2017 and May 2018, a sample of 103 elderly living in Social care centers or autonomous were recruited. Both gender individuals were included when older than 60 years, able to walk 20 meters without aids and have not regular physical activities last 6 months. The exclusion criteria were: inability to understand and speak Latvian , an acute medical illness in the past 3 months, severe health problems (e.g. recent cardiac infarction, uncontrolled diabetes or uncontrolled hypertension), unstable cardiovascular diseases, metabolic disorders (e.g., type 2 diabetes), major orthopaedic (e.g., osteoarthritis) or neurological diseases that prevent participation, medications that act on neuronal level (e.g. Psychotropic medications), cognitive impairments (Mini-Mental State Examination < 20 points). Forty-one participants had to be excluded. The mean age of the participants was 70.6±6.8, BMI 27.4±1.6, included female in the research was 40 and male 22.

The LASE (Latvian Academy of Sports Education) committee on ethics approved the study protocol. Written informed consent, in accordance with the Declaration of Helsinki about ethical principles in the research involving human subjects, was obtained from all the participants.

Clinical Assessment

Full medical examination and collection of gender, age, weight and height were performed. Body mass index (BMI, in kg/m^2) was calculated based on anthropometry measurements.

Physical Performance Measures

Physical performance was measured using the Short Physical Performance Battery (SPPB) (Guralnik et al., 1994). The SPPB includes static balance measured in the sequence of three positions (side-by-side, semi-tandem and full tandem balance). If the first position is held for 10 seconds participant receives 1 point and follows the next position where the same scoring approach is applied. In the third position participant receives 2 points if maintains it 10 seconds. The second test of SPPB is gait speed (timed 4-meter walk at a self-selected pace (best score (the shorter time) of two test performances is used). If time is less than 4.82 seconds the maximal score of 4 points is received. Longer the time spent performing test the lesser points received. The same point scoring system applies to chair stand test (ability and time needed to stand five times as quickly as possible with arms folded across the chest from a straight-backed chair) where the maximum score of 4 points participant receives if chair stand up time is 11.19 seconds or less. In each of the three tests the maximum score can be 4 points, the minimum - 1 point. If unable to perform the test - 0 points (Guralnik, Ferrucci, Simonsick, Salive, & Wallace, 1995). These measures have a high test-retest reliability ($r > 0.9$) (Ostir, Volpato, Fried, Chaves, & Guralnik, 2002).

Cognitive function evaluation

The selected tests are associated with the component factors underlying EFs (executive function): divided attention, alertness, working memory, and selective attention (Alvarez & Emory, 2006; Grady, 2012; Van Vleet et al., 2016). RehaCom software 6.7 (HASOMED GmbH, Magdeburg, Germany) was used to evaluate EF. Test results are presented as the % of Z score. In the literature % of Z score presents norms from very conspicuous, conspicuous, but not pathologic deviations from norm and normal range (Sturm, 2002; Sturm & Willmes, 2001; Sturm, Willmes, Orgass, & Hartje, 1997).

Divided attention *(3 min without practice)*

The subject must work on visual and auditive tasks in parallel. Five circles with openings at changing positions must be observed. When the circle is closed, the subject must press the answer-button. Synchronously, high and low tones are presented alternatively. When the same tone sounds two times in a row, the subject must press the answer-button. Correctness of the visual and auditive answers as well as reaction time are evaluated and % of Z score is calculated (Sturm et al., 1997).

Selective attention *(2 min without a short introduction and one exercise)*

During the test, a visual stimulus is displayed on the screen. Randomly one of two divergent stimuli appear. In the case of the horizontal striped square, quick action is required, in case of the vertical stripes, no action is required. Action should be to press a certain button. Correctness of the answers and reaction time is evaluated and calculated into % of Z score (Sturm et al., 1997).

Alertness *(maximum of 6 min)*

In this test, the tonic alertness, the phasic alertness, and intrinsic alertness are detected. In the first phase the response time when full quadrate appears on the screen is measured. The participant must press a button as quick as possible in response. In the second phase, reply time to the same quadrate is detected while a beep sound was played before the quadrate emerges. The participant must wait until the quadrate emerges on the screen to press the button (not reacting to the beep sound). Correctness of the answers and reaction time is evaluated and calculated into % of Z score (Sturm & Willmes, 2001).

Working memory *(7 min or by the time the maximum number of mistakes is reached)*

During the test, 10 dots in one circle are presented on the screen. Dots each individually will light up in red and change again to white. The sequence to memorize starts with two dots. After the pattern was shown the same sequence must be marked in the correct order. This module is adaptive. After two accurate reproductions of the sequence, the number of dots to remember will be increased. If the participant fails, the number of dots which are to memorize will be reduced. The higher the level (meaning more dots participant can remember) the higher is test score. In additional, correctness of the answers is evaluated and score is given. At the end both parameters are calculated as a % of Z score (Sturm, 2002).

Core stability test

A Chattanooga Stabiliser pressure biofeedback pad (Chattanooga Group, Inc., Austin, TX, United States) and a stopwatch were used during the test. Participant was lying in prone position. The inflatable pad was placed centrally beneath the abdomen with the lower edge at the level of the anterior superior iliac spines. The subjects were trained on how to contract their TrA using an abdominal drawing-in maneuver (Richardson, Toppenberg, & Jull, 1990). They could practice no more than three practice tries to prevent premature fatigue. Readings were taken at the start and after the 10-second contraction (timed using a stopwatch), over three consecutive contractions. Changes in pressure readings were numerated from the baseline of 70 mm Hg, meaning, that 70 mm Hg (the start of the test) – end value (value taken after the 10 seconds) = final score of the test (change in the pressure). The mean change in pressure at the end of the three contractions was calculated. The better performance of abdominal draw in manoeuvre, the lesser final score appears. Research have established that normal response of mean change in pressure is ≥ -4 mm (Hodges & Richardson, 1996; Richardson & Jull, 1995), -2 to -4 mid-range (uncertain response) (Cairns, Harrison, & Wright, 2000), ≤ -2 mm Hg (abnormal response) (Richardson & Jull, 1995).

Statistical analysis

Power analysis was performed using G*Power 3.1.9.2 software to establish the type 2 error (Faul, Erdfelder, Buchner, & Lang, 2009). SPSS statistics application version 23 (IBM Corp. in Armonk, New York, United States) was used for further research. Assumptions for linear relationships, homoscedasticity (established by scatterplots and partial regression plots), multicollinearity (established through an inspection of correlation coefficients and Tolerance/Variance inflation factors values) and independence of observation (measured by Durbin-Watson statistic) to perform hierarchical multiple regression analysis, were checked ensuring adequacy of the values. Firstly, hierarchal multiple regression analysis was executed with the controlled variable that is age (proved to be main determinant affecting neurogenic and myogenic factors (Clark & Manini, 2008; Clark, Taylor, Hong, Law, & Russ, 2015)) serving as an independent variable. In the second stage new set of independent variables together with the first step independent variable were analysed to establish whether new independent variables deliver additional effect to the core stability as it may appear considering the evidence (Suri et al., 2009). In the third stage cognition was added to the mentioned variables assuming that it might influence core stability as well.

Results

The participants overall showed average results in the tests. Except, in the SPPB test the outcomes were higher than in the normal population with similar age. Mean body mass index (BMI) 27.41 kg/m2 shows overweight of the participants (Table 1).

Table 1 ***Tests results stated as mean ± SD (N=62)***

Sum of SPPB (points)	8.7 ± 1.8
Static balance	2.9 ± 0.9
Leg strength	2.6 ± 1.1
Walking speed	3.2 ± 0.8
Rehacom Cognition score (%)	51.6 ± 9.2
Prone test (mm Hg)	3.1 ± 1.2*

**Score is as an absolute value*

Interpretation of tests results:

SPPB, Short Physical Performance Battery (0 points - the highest mortality risk, 12 points - the lowest mortality risk in following years); Static balance, Leg strength and Walking speed (in each test 0 points - the highest mortality risk, 4 points – the lowest mortality risk in following years);

Rehacom Cognition score (≥ 15.9% normal range, 2.3% to 15.9% results conspicuous, but not patalogic, ≤ 3.3% very conspicuous deviation from norm); i

Prone test's (in the start of the test onset score 70mm Hg) end value (value taken after the 10 seconds) ≤ 66 mm Hg (or ≥ -4 mm Hg change in pressure) normal response, 68 mm Hg to 66 mm Hg (-2 to -4 mm Hg) mid- range (uncertain response), ≥ 68 mm Hg (≤ -2 mm Hg) abnormal response.

The power analysis of the sample size adequacy presents high power that is 0.98. Model 2 and Model 3 fit satisfactory to the data. The core stability is significantly predicted by them $F = 3.31$, $p < .05$ and $F = 5.18$, $p < .01$ (Table 2). Static balance ($\beta = .34$, $p <.01$ in Model 2 and $\beta = .31$in Model 3, $p <.05$) and cognition ($\beta = .35$ in Model 3, $p < .01$) present greater effect on the core stability from the given outcomes. Model 2 explains 18% share of variability in the dependent variable ($R^2 = .18$). Independent variables in Model 3 explained 31%

of the variance of core stability (R^2 = .31). The statistically significant influence on core stability comes from static balance and cognition. Both showing a similar proportion that influence core stability.

Table 2 ***Summary of Hierarchical Regression Analysis for variables predicting core stability***

	Model 1			Model 2			Model 3		
Variable	B	SE B	β	B	SE B	β	B	SE B	β
Age	.03	.02	.16	.03	.02	.19	.03	.02	.19
Functional performance elements									
static balance				.48	.17	.34**	.44	.16	.31*
leg strength				.05	.14	.04	.05	.13	.04
walking speed				.20	.19	.13	.18	.18	.12
Cognition							.04	.01	.35**
R^2		.02			.18			.31	
F for change in R^2		1.77			3.31*			5.18**	

B, unstandardized coefficients; SE B, standar error of unstandardized coefficients; β, standardized coefficients; R^2, coefficient of determination; F, F-ratio
**p < .05. **p < .01*

Discussion

The present research tested the voluntary activation of TrA. It increments intra-abdominal pressure and tensions the thoracolumbar fascia (Borghuis, Hof, & Lemmink, 2008) that could radiate to lower limb anatomical structures (Barker, Briggs, & Bogeski, 2004; Norton-Old et al., 2013; Myers, 2013). If the muscular system is perceived as a multiple mechanism of myofascial meridians described by Mayers (Myers, 2013), consequently relatively reliable relationships could be found between the trunk region and lower limbs. However, our study does not show a significant connection between these parameters, respectively core stability with leg muscle strength or gait speed. Only the minor degree influence of aforementioned variables on core stability was demonstrated that wasn't statistically significant. Locomotion primarily is an automated process (Haefeli et al., 2010), where central pattern generator (CPG), supposedly, localized in the spinal cord, plays a substantial role in controlling the movements of the corresponding limbs (Ivanenko, Poppele, & Lacquaniti, 2006). It is unknown whether the appearance of closer relationships between the gait and core stability would be substantial if the subjects instead of voluntary rather automatically have performed core stability test (Hodges & Richardson, 1996) therefore subconsciously activating neural circuits between the mentioned variables.

However, spinal locomotor (Grillner, 2011) and nonlocomotor (Borroni, Montagna, Cerri, & Baldissera, 2008) activity are also under supraspinal control, where it executes the CPG's organized sequencing of motor activity in locomotion (Drew, Prentice, & Schepens, 2004). That goes in line with other studies stating, that the coupling of corticospinal with propriospinal circuits may result in partial synchronization of activation components (Haefeli et al., 2010; Ivanenko et al., 2006). Our study shows significant relationships between cognition (e.g. EF) and core stability underlining the possible presence of sensorimotor pathways connecting (pre)frontal lobe and TrA. It has been described, that core stability is affected by cognitive programming that is based on stored central commands that interchange in signalling with voluntary adjustments (Radebold, Cholewicki, Polzhofer, & Greene, 2001). These relationships may be crucial during the specific locomotor tasks that may cause senior to fall like change in the direction, circumvention of an obstacle or stepping over it (Haefeli et al., 2010). The authors (Haefeli et al., 2010) state, that drive from supraspinal centers (e.g. Brodmann areas 9, 10, 11 associated with cognition) performing the obstacle task is stronger than during walking. Therefore, the implementation of cortical and lower spine area tasks in the exercise sessions might be worth of further investigation (Haefeli et al., 2010; Ivanenko et al., 2006), because this approach may benefit during the day by day activities when carrying out specific locomotor tasks.

Lower supraspinal or so-called subcortical levels whose certain properties when challenged influence balance also may affect core stability (Radebold et al., 2001). The findings of our study show that static balance impacts core stability, therefore it can be assumed that neural pathways of cognition and balance (both probably interacting with each other) play a substantial role in core functioning. It is known, the brain stem level pathway that coordinates vestibular (being considered as the main balance controller (Anderson & Behm, 2005)) and visual input (Radebold et al., 2001) is substantial during stepping over obstacles, cos neurons in the brainstem ensure that modifications of the motor cortex are superimposed on an appropriate base of postural support (Drew et al., 2004). Spinal proprioception mechanism and equilibrium have been reported to be crucial in minimizing the postural destabilization (Ebenbichler, Oddsson, Kollmitzer, & Erim, 2001). Probably, the analysis of correlation between the spinal functioning mechanism and brainstem and/or prefrontal lobe would depict more explicit inside if our research included more tests related to functional performance. For instance, a dynamic balance test where the participant must walk 10 meters in tandem gait (Ramnath, Rauch, Lambert, & Kolbe-Alexander, 2018) also might be an important determinant during the specific motor activities.

However, more studies are warranted in this field. In addition to evidence of static balance impacting core stability it should be clarified that core stability test presented in our study measures participants' ability to activate TrA and endurance (ability to maintain TrA contraction for 10 seconds) (Cairns et al., 2000). Even though, core endurance seemingly is an important parameter during the daily activities (Borghuis et al., 2008), the strength of core muscles may play an important role. Therefore, the effect of static balance on core strength should be investigated in the future as there is little research documenting it (Borghuis et al., 2008).

From the evidence collected in the present research, it appears that the functioning of the sensorimotor system and its main controllers respectively both pre-frontal cortex (cognition) and vestibular component (balance) affect core stability significantly more than walking speed or leg strength which are mostly dictated by spinal circuits. This might be crucial during everyday activities when specific locomotor tasks are performed challenging higher levels of CNS (central nervous system) to preserve equilibrium of the trunk.

Limitations of the study

Different approaches to testing might present a more explicit look at the research. For example, to measure both strength and endurance of core more appropriate may be Sahrmann core stability test (Stanton, Reaburn & Humphries, 2004). The best approach to functional performance testing yet has to be defined. In the next researches performance of Grip strength, Functional reach and other tests could be accommodated. For instance, the Timed Up and Go test could be more appropriate, because includes walking, turning, stopping elements that occur during the real-time obstacle overcome. The results of multiple regression showed, that only one-third of core stability was explained from measured variables, therefore settling space for further speculations and uncertainties.

Conclusion

The core stability is significantly affected by cognition and static balance identifying the presence of neural circuits between them which when challenged may play a crucial role during the locomotor tasks.

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