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The correlation between physical and emotional stabilities: a cross-sectional observational preliminary study

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ABSTRACT

Background: Postural stability and gait are affected by an individual's emotional state. Physical therapy practice does not usually include an explicit assessment of the individual's emotional status. In contrast, complementary movement therapies often include the assessment of "grounding quality", which refers to the individual's physical and emotional stabilities. This study examined the correlation between conventional physical stability measures and grounding quality.

Method: A computerized balance board and an inertial sensor system measured the postural stability and gait parameters of 36 healthy volunteers (aged 19–35 years). Grounding was assessed using an observation-based assessment tool (Grounding Assessment Tool [GAT]). Spearman's correlation and Cohen's standard were used to assess correlation.

Results: No correlation was observed between gait parameters and GAT scores. However, significant negative moderate correlations were noted between postural sway measures and scores of several GAT items in the more demanding stance conditions.

Conclusion: Although grounding quality and sway measures are somewhat correlated, they focus on different aspects of movement stability. A comprehensive assessment and holistic intervention strategies require incorporating multiple approaches to stability assessment. Further research is necessary to determine the contribution of combining these approaches among individuals with balance impairments.

KEY MESSAGES

- Gait stability measures were not correlated to "grounding quality" (a measure of emotional regulation and emotional awareness).
- Postural sway measures were found to be correlated to "grounding quality" items in the more demanding stance conditions.
- A comprehensive evaluation of an individual's stability may facilitate reliable and valid objective measurement instruments for both physical and emotional aspects of the movement.

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Postural stability; gait; balance; emotional awareness; assessment; grounding

Introduction

Balance is defined as the ability to maintain the body's centre of mass within the limits of the base of support [1]. Maintaining one's balance is necessary for all daily functional tasks, particularly those involving postural stability and gait. Both postural stability and gait pattern are affected by an individual's emotional and psychological state [2–4]. For example, depression significantly affects the gait pattern in naturalistic, everyday life settings [5], and the low mood was demonstrated to alter balance performance in healthy male subjects [6]. Furthermore, physical stability during functional tasks, even those which may be considered automatic, requires some degree of emotional and cognitive attention [7–12]. Accordingly, posture control entails a dynamic interplay between self-awareness, attention allocation, and motor processes during active movement [13].

Balance assessment is a crucial component of physical therapy assessment in different practice areas. To this end, various validated and reliable standardized measures based on the evidence-based health care

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approach have been used [14]. However, as mentioned, the assessment of balance should also consider an individual's internal emotional state and level of arousal. To the best of our knowledge, the current tools for assessing static and dynamic balance used by physical therapists do not facilitate an explicit and structured assessment of an individual's level of arousal and awareness.

Therapists involved in dance/movement therapy (DMT) use a tool to assess physical and emotional stabilities by evaluating an individual's "grounding quality" [15]. The psychotherapist Alexander Lowen (1910–2008), who first coined this term, claimed that the nature of human beings requires a solid connection to the ground/earth in terms of physicality, emotion, and energy [16,17]. Lowen described a physiologically and physically stable person as the one who "has his feet on the ground" and "who is in touch with reality" [18]. Interventions targeted at increasing the level of groundedness using movement techniques are in everyday clinical use by psychotherapists and dance movement therapists who treat a variety of patients with emotional impairments manifesting in physical impairments and symptoms, such as depression, post-traumatic stress disorder, and somatoform disorders [19–21]. Movement interventions for enhancing grounding are based on the rationale that the body and mind are connected. Thus, therapeutic interventions should combine the muscular and nervous systems with the cognition and emotions of an individual [22].

In the current study, we used traditional assessment tools for postural stability and gait analysis, i.e. a force plate and a sensor-based gait system, combined with an observation-based assessment tool called the "Grounding Assessment Tool" (GAT), which evaluates emotion regulation and emotional awareness as reflected by the individual's quality of grounding. Accordingly, this exploratory study aimed to examine the correlation between physical stability (and Spatio-temporal measures) and grounding quality in individuals with no known balance, emotional, or cognitive impairments.

Materials and methods

Participants

Thirty-six healthy volunteers (26 women and 10 men) between the ages of 19 and 35 years (median, 26.51 years; standard deviation, 3.71 years) participated in the study. The convenience sampling method was used to recruit participants from among university students or staff through advertisements posted on various social media forums at the university. The exclusion criteria included conditions that may affect gait and balance, such as (a) orthopaedic or neurological impairments, (b) cardiovascular or pulmonary disease, (c) lower limb musculoskeletal injury over the last year, (d) vestibular disorders, such as vertigo, and (e) balance disorders.

Assessment tools

Postural stability assessment

Postural stability was measured using the TYMO® balance board (Tyromotion, Graz, Austria, https://tyromotion.com/), a portable posturography tool. The system provides data on the body sway, and these data provide indicators of postural stability. This system is used in research and clinical settings [23–25].

Gait analysis

APDM movement monitoring inertial sensor-based gait system (APDM Inc., Portland, OR, USA) utilizing wireless, wearable, and portable sensors was used for collecting spatiotemporal gait measures [26]. This system comprises six inertial sensors, each containing tri-axial accelerometers, gyroscopes, and magnetometers [27]. The raw data are automatically streamed to a laptop, where they are processed and calculated by the system's Mobility Lab™ software package [28]. The following spatiotemporal outcome measures were collected: stride length, cadence, velocity, swing and stance time, and stride time.

Grounding assessment

Grounding quality was assessed using GAT, which is an observation tool. The GAT includes 13 items, each rated on a 5-point Likert-type scale ranging from 1 (very low level of grounding) to 5 (very high level of grounding). The following four factors are considered for assessment: (1) fluid and rhythmic movement, (2) emotional expression in movement, (3) pattern of foot placement, and (4) lack of stability and weightiness. The GAT has been validated and demonstrated to have good internal consistency ($\alpha = 0.850$), high inter-rater reliability (Kendall's range from 0.789 to 0.973), and an intraclass correlation coefficient ranging between 0.967 and 1.00 [15].

Procedures

Eligible participants were recruited for a 1-h session. The study was approved by the institutional review board at the X [29]. After receiving the relevant information regarding the study and before participation, all participants signed an informed consent form. Participants were instructed to wear comfortable clothing and to move around with bare feet during the session. At the beginning of the session, all participants filled out a questionnaire regarding age, sex, medication consumption, background illnesses, the field of study, and educational level. The session consisted of the following three parts: (1) postural stability, (2) gait analysis, and (3) grounding assessment.

All parts were assessed in a random order created by a computerized table. The session setting was a $20 \times 175\,m^2$ hall empty of objects used during the grounding assessment and a quiet 10-m long corridor used for the gait test. Postural stability assessment and gait analysis were conducted by the same two experienced physical therapists.

Postural stability assessment

Assessment of postural stability during quiet standing included four conditions tested while standing directly on a force platform (Tymo plate by Tyromotion, Graz, Austria). The order of the following conditions was fixed: eyes open and closed while standing on a firm surface, and eyes open and closed on a compliant foam mat placed on top of the force platform.

Gait analysis

Five APDM sensors were attached with Velcro straps (one on the pelvis, one on the middle of each thigh, and one on the middle of each shank). Participants were asked to walk back and forth at a comfortable speed (self-determined natural speed) for 5 min along a 10-m path.

Assessing grounding quality

Grounding quality was assessed when a group of 4–5 participants moved around in a room for 10 min. The group size was determined by the ability to capture high-quality video footage of the movements of all participants throughout the room.

The walking period was subdivided into three sections: (1) Walking (3 min): the instruction was initially to maintain a normal walking pattern throughout the room. This was followed by an instruction to "look for new routes in the space", followed by an instruction to "increase the pace of walking", and finally to "slow down"; (2) Spontaneous free movement in the room (3 min): first, instruction was provided to "perform a movement that begins in your body" and "you can imagine inner music", then to "let the movement move along the whole body", and finally to "move with this movement in space and try to change the position in space"; and (3) Movement at different rhythms in a circle together with the rest of the group participants (4 min): the initial instruction here was to "walk in a circle and try to synchronize with the rhythm of the group", then routine rhythmic non-lyrics music was played with the instruction to "synchronize with the music rhythm", and finally an instruction of "each one will suggest a movement and others will synchronize with that movement". The guidelines for movement are based on ways of examining grounding as described in the literature; these include various options for assessing the quality of the movement [15]. The entire movement sequence of the group was video recorded. This session was led by a dance movement therapist. The ranking was performed later by two dance movement therapists (E.S.E. and M.P.) who watched each participant's video and independently ranked the participant's grounding quality on the GAT scale [15].

Statistical analyses

Descriptive statistics (mean, standard deviation, median, minimum, and maximum) were computed for the participants' balance and gait analysis outcome measures, total GAT score, and four factors of GAT. As the continuous parameters failed to meet the assumptions necessary for conducting Pearson's correlation, and the sample size was small, we used Spearman's correlation to test the correlation between the balance and gait analysis outcome measures, total GAT total score, and four factors of GAT. Cohen's standard was used to determine the strength of the relationship by evaluating the correlation coefficient [30]. Correlation coefficients between 0.10 and 0.29 indicate a small effect size, coefficients between 0.30 and 0.49 indicate a moderate one, and coefficients $\geq$0.50 indicate a large effect size. Accordingly, a threshold of coefficients $\geq$0.3 was set as an acceptable relationship. The data were analyzed using SAS version 9.4, and a *p*-value of $<$.05 was considered statically significant.

Results

Participant characteristics are presented in Table 1. The participants had a normal body weight as indicated by a mean value of BMI ($21.78\,kg/m^2 \pm 2.49$). Approximately 70% of the participants had no medical problems. While the remaining subjects did comply with the study's inclusion criteria and did not suffer from conditions that could affect gait or balance, they did present with various medical conditions, such as

Table 1. Participants' demographic characteristics ($n = 36$).

Characteristics		
Age, year *M* (*SD*)	26.5 (3.7)	
Body mass index, kg/m^2 *M* (*SD*)	21.78 (2.49)	
	N	%
Sex		
Female	26	72.2
Male	10	27.8
Field of study		
Physiotherapy	13	38.8
Dance movement therapy	12	36.1
Art	8	25
Other	3	8.3
Medical problem		
Yes	11	30.6
No	25	69.4
Medication consumption		
Yes	8	22.2
No	28	77.8

M: mean; *SD*: standard deviation; kg: kilograms; m: metre.

gastrointestinal problems, thyroid dysfunction, pulmonary disease, skin disease, and neck pain. Approximately 78% of the participants did not consume medication regularly, with the remaining consuming medications to control for the mentioned medical problems. None of the consumed medications have known effects on balance. The results of postural stability assessment, and gait analysis, are detailed in Table 2. The mean total score of the GAT was 3.8 ± 0.86 (out of 5). The scores of the four GAT factors are detailed in Table 2.

The correlation between all gait measures and the GAT scores was non-significant. The correlation analysis results between the postural stability measures and GAT scores are presented in Table 3. Significant

Table 2. Descriptive results of the postural stability assessment, gait analysis, and grounding scores of study participants ($n = 36$).

Variables	Mean ± *SD*	Median	Minimum–maximum
Balance outcome measures: anterior-posterior			
F-EO (cm)	2.67 ± 1.26	2.00	1.00–6.00
F-EC (cm)	2.42 ± 0.87	2.00	1.00–6.00
C-EO (cm)	3.61 ± 1.69	3.00	0.00–8.00
C-EC (cm)	4.36 ± 1.76	4.00	2.00–9.00
Medio-lateral			
F-EO (cm)	2.42 ± 2.76	1	0–12
F-EC (cm)	1.72 ± 1.28	1	1–7
C-EO (cm)	3.53 ± 3.76	3	0–19
C-EC (cm)	2.72 ± 2.01	2	0–10
Gait outcome measures*			
Stride length (cm)	118.54 ± 12.37	122.37	90.16–134.02
Cadence (steps/min)	99.18 ± 7.95	99.89	78.78–120.89
Velocity (cm/s)	102.14 ± 14.17	105.27	71.75–128.16
Swing time (s)	0.50 ± 0.03	0.49	0.43–0.59
Stance time (s)	0.70 ± 0.06	0.70	0.56–0.85
Stride time (s)	1.21 ± 0.09	1.20	0.99–1.41
Grounding quality-GAT scores			
Total GAT score	3.80 ± 0.86	3.92	1.77–5.00
Fluid and rhythmic movement score	3.51 ± 1.11	3.60	1.00–5.00
Emotional expression in movement score	4.28 ± 0.93	4.33	1.00–5.00
Pattern of foot placement subcategory score	3.39 ± 1.64	4.00	1.00–5.00
Lack of stability and weightiness score	4.09 ± 0.96	4.33	1.00–5.00

GAT: grounding assessment tool; F-EO: firm surface with eyes open; F-EC: firm surface with eyes closed; C-EO: compliant foam with eyes open; C-EC: compliant foam with eyes closed; SD: standard deviation.
*All the gait outcome measures were collected from 30 participants.

Table 3. Results of Spearman's correlations between the grounding assessment tool (GAT) and the balance and gait outcome measures (*r*, *p*-values) ($n = 36$).

Variable GAT scores	Total score	Fluid and rhythmic movement score	Emotional expression in movement score	Pattern of foot placement score	Lack of stability and weightiness score
Balance outcome measures: anterior-posterior					
F-EO (cm)	−0.18, NS	−0.08, NS	−0.19, NS	−0.25, NS	−0.16, NS
F-EC (cm)	−0.34, 0.04	−0.26, NS	−0.45, 0.006	−0.40, 0.02	−0.08, NS
C-EO (cm)	0.15, NS	0.15, NS	0.09, NS	0.06, NS	0.15, NS
C-EC (cm)	−0.6, NS	−0.24, NS	−0.18, NS	−0.04, NS	−0.26, NS
Medio-lateral					
F-EO (cm)	−0.25, NS	−0.18, NS	−0.28, NS	−0.25, NS	−0.16, NS
F-EC (cm)	−0.13, NS	−0.03, NS	−0.07, NS	−0.27, NS	0.008, NS
C-EO (cm)	−0.31, 0.06	−0.29, 0.09	0.09, NS	−0.42, 0.01	−0.27, NS
C-EC (cm)	−0.46, 0.005	−0.36, 0.03	−0.26, NS	−0.31, 0.07	−0.49, 0.002

GAT: grounding assessment tool; F-EO: firm surface with eyes open; F-EC: firm surface with eyes closed; C-EO: compliant foam with eyes open; C-EC: compliant foam with eyes closed; NS: not significant.

negative moderate correlations were noted between the anterior-posterior sway while standing on a firm surface with eyes closed and the following GAT scores: total score, emotional expression in movement score, and the pattern of foot placement score.

Regarding the mediolateral sway, correlations with the GAT scores were observed only on the compliant surface. Standing with eyes open showed a significantly negative moderate correlation with the pattern of foot placement, with a similar trend also noted for the total score and the fluid and rhythmic movement score. Standing with eyes closed demonstrated significant negative correlations with all the GAT scores, except for the pattern of foot placement score where only a trend was observed, and with emotional expression in movement score where no significant correlation was noted.

Discussion

Our novel study revealed that there was no correlation between any gait measures and the GAT scores. In contrast, significant negative moderate correlations were noted between anterior-posterior and medio-lateral sways and scores of some of the GAT items, indicating the lower quality of grounding as the sway amplitude increased. These results reinforce the idea that grounding quality is related to physical stability strategies. The observed correlations appeared mainly in the more demanding stance conditions (firm surface with eyes closed, compliant foam with eyes open, and compliant foam with eyes closed). Moreover, the correlation pattern in the medio-lateral direction was different from that in the anterior-posterior direction. For example, anterior-posterior demonstrated correlations with GAT on the firm surface only with closed eyes, and correlations in medio-lateral sway were observed on the compliant surface with eyes open and closed.

The results indicating no correlation between the spatiotemporal measures of gait and the GAT score are interesting since the GAT focuses primarily on evaluating movement in space while walking. As in this case, a lack of correlation between conventional gait variables and GAT scores may indicate that the two measures evaluate entirely different aspects of the movement. This establishes the premise that the GAT is related more to emotional awareness and emotional regulation during movement rather than walking ability as measured by the spatiotemporal outcome measures. Accordingly, if the clinicians' aim is to assess emotional aspects during walking, they cannot rely solely on the traditional gait analysis and should expand their toolbox to include tools, such as the GAT.

Our results demonstrate that assessing the pattern of foot placement using the GAT negatively correlated with postural stability, as reflected in sway in both directions during the more physically demanding conditions. The foot contributes to stability by providing mechanical support for the whole body and by providing sensory input from the plantar tactile mechanoreceptors [31,32]. A decline in sensory tactile and muscular feedback of the foot was found to be correlated with postural control and increased risk of falls in older adults and in peripheral neuropathies (due to diabetes mellitus or post-cymotherapy) [33]. The function of the foot is also affected by the occupation of the individual, as indicated in a study demonstrating lower foot function and foot health in ballet dancers compared with non-dancers [34]. Additionally, our results indicate compatibility between physical aspects of stability achieved during stance as measured by the degree of sway and Lowen's theory, which claims that the level of grounding corresponds to the degree to which the foot completely touches the ground [16]. Accordingly, observing how the foot is spread on the floor and maintaining contact with the floor, as well as noting the gradualness of weight transfer from heel to toe when walking, can provide important information regarding the patient's emotional state.

Our study highlights a distinction between the anterior-posterior and medio-lateral directions in terms of the existence of significant correlations between sway amplitudes and grounding quality in the physically demanding conditions, with the medio-lateral direction showing a higher correlation with the GAT than the anterior-posterior direction. Therefore, the integration of emotional stability with physical stability behaves differently in each of the sway directions. This assumption is supported by previous studies that have demonstrated that anterior-posterior and medio-lateral sways are controlled by independent strategies [35,36], with the medio-lateral sway demonstrating higher corticospinal excitability than the anterior-posterior sway [31]. This may indicate that the medio-lateral sway requires greater neural resources [37,38]. Furthermore, it was demonstrated that postural demands may affect the direction of the postural sway [39]. The current results indicate a higher correlation between postural stability in both anterior-posterior and medio-lateral directions and the total GAT score with eyes closed compared with eyes open while standing on a compliant form surface. These results point to the possible role of visual input on the individual's emotional stability during demanding physical conditions. This also suggests that the increased postural threat due to the elimination of the visual input in physically demanding conditions may increase emotional instability. Our findings are supported by those from previous reports suggesting that anxiety is increased due to increased postural threat [40,41], particularly when visual information is not available [42]. The possible explanation is that physical and emotional stability is mediated by shared neural circuits, in particular, the network of parabrachial nuclei and interconnection with the central nucleus of amygdaloid [4,43]. Physical therapists and dance/movement therapists can use our results to optimize the treatment process. Postural stability training should be tailored to the individuals' levels of emotional stability.

This study has several limitations that should be considered while interpreting our results. The small number of subjects limits the interpretation of the current findings. Accordingly, further studies should include more participants to consider possible confounding factors of physical stability, such as age, sex, and body mass index [44–46]. An additional limitation is the non-inclusion of individuals with a balance deficit or with abnormal gait patterns. Further studies on individuals with such deficits due to various pathologies (e.g. post-stroke patients or those with arthritis) are required to validate our results. It is also possible that the inclusion of participants with emotional impairments would have changed the results and/or strengthened the observed correlation pattern.

In conclusion, our study serves as the basis for continuing studies that will examine the clinical implication of our findings in-depth. These preliminary results justify and encourage further exploration of the relationship between the body and mind measured by reliable and valid objective measurement instruments for both physical and emotional aspects of the movement. Additionally, it highlights the importance of research and clinical collaborations between multiple health professionals, which may lead to more complete assessments and holistic intervention strategies.

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Ethical approval

The study involving human participants was reviewed and approved by the University of Haifa, the Research Authority, and the institution's ethics committee (approval no. 2073). The participants provided their written informed consent before participating in this study.

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Data availability statement

Data are available by direct contact with the corresponding author (michal.elboim@gmail.com).

References

[1] Shumway-Cook A, Woollacott MH. 2007. Motor control: translating research into clinical practice. Philadelphia, PA: Lippincott Williams & Wilkins.
[2] Brown LA, Polych MA, Doan JB. The effect of anxiety on the regulation of upright standing among younger and older adults. Gait Posture. 2006;24(4):1678–405.
[3] Naugle KM, Hass CJ, Joyner J, et al. Emotional state affects the initiation of forward gait. Emotion. 2011;11(2):267–277.
[4] Rusnakova K, Gerych D, Stehlik M. Relationship between personality traits and postural stability among Czech military combat troops. Int J Psychol Behav Sci. 2021;15(3):151–157.
[5] Adolph D, Tschacher W, Niemeyer H, et al. Gait patterns and mood in everyday life: a comparison between depressed patients and non-depressed controls. Cogn Ther Res. 2021;45(6):1128–1140.
[6] Bolmont B, Gangloff P, Vouriot A, et al. Mood states and anxiety influence abilities to maintain balance control in healthy human subjects. Neurosci Lett. 2002;329(1):96–100.
[7] Brown LA, Sleik RJ, Polych MA, et al. Is the prioritization of postural control altered in conditions of postural threat in younger and older adults? J Gerontol A Biol Sci Med Sci. 2002;57(12):M785–M792.
[8] Marsh AP, Geel SE. The effect of age on the attentional demands of postural control. Gait Posture. 2000;12(2):105–113.
[9] Nonnekes J, Dibilio V, Barthel C, et al. Understanding the dual-task costs of walking: a StartReact study. Exp Brain Res. 2020;238(5):1359–1364.

[10] Teasdale N, Bard C, LaRue J, et al. On the cognitive penetrability of posture control. Exp Aging Res. 1993; 19(1):1–13.
[11] Woollacott M, Shumway-Cook A. Attention and the control of posture and gait: a review of an emerging area of research. Gait Posture. 2002;16(1): 1–14.
[12] Yogev-Seligmann G, Hausdorff JM, Giladi N. The role of executive function and attention in gait. Mov Disord. 2008;23(3):329–342; quiz 472.
[13] Beauchet O, Allali G, Berrut G, et al. Gait analysis in demented subjects: interests and perspectives. Neuropsychiatr Dis Treat. 2008;4(1):155–160.
[14] Djulbegovic B, Guyatt GH. Progress in evidence-based medicine: a quarter century on. Lancet. 2017; 390(10092):415–423.
[15] Shuper Engelhard E, Pitluk M, Elboim-Gabyzon M. Grounding the connection between psyche and soma: creating a reliable observation tool for grounding assessment in an adult population. Front Psychol. 2021;12:621958.
[16] Lowen A, Lowen L. 1977. The vibrant way to health: a manual of exercises.Manhattan, NY: Harper & Row.
[17] Lowen A. 2004. Honoring the body: the autobiography of Alexander Lowen, M.D. Alachua, FL: Bioenergetics Press.
[18] Lowen A. 1993. Depression and the body: the biological basis of faith and reality. Baltimore, MD: Penguin Books.
[19] Ko KS. A broken heart from a wounded land: the use of Korean scarf dance as a dance/movement therapy intervention for a Korean woman with Haan. Arts Psychother. 2017;55:64–72.
[20] Nickel M, Cangoez B, Bachler E, et al. Bioenergetic exercises in inpatient treatment of Turkish immigrants with chronic somatoform disorders: a randomized, controlled study. J Psychosom Res. 2006;61(4): 507–513.
[21] Pylvänäinen PM, Muotka JS, Lappalainen R. A dance movement therapy group for depressed adult patients in a psychiatric outpatient clinic: effects of the treatment. Front Psychol. 2015;6:980.
[22] Guest D, Parker J, Williams SL. Development of modern bioenergetic analysis. Body Mov Dance Psychother. 2019;14(4):264–276.
[23] Held JP, Ferrer B, Mainetti R, et al. Autonomous rehabilitation at stroke patients home for balance and gait: safety, usability and compliance of a virtual reality system. Eur J Phys Rehabil Med. 2018;54(4): 545–553.
[24] Maranesi E, Riccardi GR, Lattanzio F, et al. Randomised controlled trial assessing the effect of a technology-assisted gait and balance training on mobility in older people after hip fracture: study protocol. BMJ Open. 2020;10(6):e035508.
[25] Pin TW, Butler PB. The effect of interactive computer play on balance and functional abilities in children with moderate cerebral palsy: a pilot randomized study. Clin Rehabil. 2019;33(4):704–710.
[26] Fang X, Liu C, Jiang Z. Reference values of gait using APDM movement monitoring inertial sensor system. R Soc Open Sci. 2018;5(1):170818.
[27] Lanovaz JL, Oates AR, Treen TT, et al. Validation of a commercial inertial sensor system for spatiotemporal gait measurements in children. Gait Posture. 2017;51: 14–19.
[28] Mancini M, King L, Salarian A, et al. Mobility lab to assess balance and gait with synchronized body-worn sensors. J Bioeng Biomed Sci. 2011;Suppl 1:007.
[29] Von Elm E. Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. BMJ. 2007;335:806–808.
[30] Cohen J, Cohen P, West SG, et al. 2013. Applied multiple regression/correlation analysis for the behavioral sciences. 3rd ed. New York, NY:Routledge.
[31] Menz HB, Morris ME, Lord SR. Foot and ankle characteristics associated with impaired balance and functional ability in older people. J Gerontol A Biol Sci Med Sci. 2005;60(12):1546–1552.
[32] Strzalkowski NDJ, Ayesha Ali R. Bent LR. The firing characteristics of foot sole cutaneous mechanoreceptor afferents in response to vibration stimuli. J Neurophysiol. 2017;118(4):1931–1942.
[33] Viseux FJF. The sensory role of the sole of the foot: review and update on clinical perspectives. Neurophysiol Clin. 2020;50(1):55–68.
[34] López-López D, Fernández-Espiño C, Losa-Iglesias ME, et al. Women's foot health–related quality of life in ballet dancers and nondancers. Sports Health. 2020; 12(4):347–351.
[35] Doheny EP, McGrath D, Greene BR, et al. Displacement of centre of mass during quiet standing assessed using accelerometery in older fallers and non-fallers. Ann Int Conf IEEE Eng Med Biol Soc. 2012; 2012:3300–3303.
[36] Winter DA, Prince F, Frank JS, et al. Unified theory regarding a/P and M/L balance in quiet stance. J Neurophysiol. 1996;75(6):2334–2343.
[37] Mehdizadeh H, Khalaf K, Ghomashchi H, et al. Effects of cognitive load on the amount and temporal structure of postural sway variability in stroke survivors. Exp Brain Res. 2018;236(1):285–296.
[38] Slobounov S, Hallett M, Cao C, et al. Modulation of cortical activity as a result of voluntary postural sway direction: an EEG study. Neurosci Lett. 2008;442(3): 309–313.
[39] Gebel A, Lehmann T, Granacher U. Balance task difficulty affects postural sway and cortical activity in healthy adolescents. Exp Brain Res. 2020;238(5): 1323–1333.
[40] Zaback M, Reiter ER, Adkin AL, et al. Initial experience of balance assessment introduces 'first trial' effects on emotional state and postural control. Gait Posture. 2021;88:116–121.
[41] Hauck LJ, Carpenter MG, Frank JS. Task-specific measures of balance efficacy, anxiety, and stability and their relationship to clinical balance performance. Gait Posture. 2008;27(4):676–682.
[42] Coco M, Fiore AS, Perciavalle V, et al. Stress exposure and postural control in young females. Mol Med Rep. 2015;11(3):2135–2140.

[43] Balaban CD. Neural substrates linking balance control and anxiety. Physiol Behav. 2002;77(4–5): 469–475.
[44] Abualait T, Ahsan M. Comparison of gender, age, and body mass index for spatiotemporal parameters of bilateral gait pattern. F1000Res. 2021; 10(266):266.
[45] Browning RC, Kram R. Effects of obesity on the biomechanics of walking at different speeds. Med Sci Sports Exerc. 2007;39(9):1632–1641.
[46] Samson MM, Crowe A, De Vreede PL, et al. Differences in gait parameters at a preferred walking speed in healthy subjects due to age, height and body weight. Aging. 2001;13(1):16–21.