GENDER AND LIMB EFFECTS ON ADULT NORMATIVE DATA FOR THE BIODEX BALANCE SYSTEM

Simonè Ferreira[1], Leon Lategan[1], Brandon S. Shaw[2], and Ina Shaw[2]

[1]*Department of Sport and Movement Studies, University of Johannesburg, Doornfontein, Johannesburg, Republic of South Africa*

[2]*School of Sport, Rehabilitation and Exercise Sciences, University of Essex, Wivenhoe Park, Colchester, Essex, United Kingdom*

Original scientific paper

DOI 10.26582/k.55.2.4

Abstract:

Posturography normative data in healthy populations is crucial for several reasons including monitoring the independence issues related to activities of daily living (ADLs), fall and incapacity avoidance, and residual injury impairment. The Biodex Balance System requires updated normative data regarding healthy persons because of recent revisions to the Biodex Balance System. Further, this study aimed to determine and compare gender and limb performance of 161 adults aged 18-55 years (n = 80 males; n = 81 females). Assessments involved both static and dynamic stability tests such as double-leg and single-leg balance tests at platform stability which served as outcome measurements. Females performed significantly (p≤.05) better on double-leg static balance (p=.031), double-leg dynamic balance (p=.002), and single-leg dynamic balance on both the left (p=.003) and right legs (p=.013) when compared to males. The normative values and findings of this study not only enable the evaluation of individual performance regarding the balance of adults but also suggest the need to use gender-stratified normative data when using the Biodex Balance System to interpret double- and single-leg, static and dynamic balance test performance.

Key words: *postural balance, posturography, health, reference values*

Introduction

Postural balance is not only an important motor ability for activities of daily living (ADL) (Halvarsson, Dohrn, & Ståhle, 2015) but is critical to avoid falls and incapacities (Fourie, et al., 2012; Mancini & Horak, 2010). It is for this reason that double- and single-leg stance postural stability testing and training form integral components of sports medicine testing and rehabilitation (Mancini & Horak, 2010; Shariat, et al., 2022). Both double- and single-leg stance postural stability testing appear to be suggestive of not only residual injury impairment, but also of future injury risk (Bahari, Naghdi, Sheikh, & Shaw, 2021; Mancini & Horak, 2010; McKeon & Hertel, 2008).

That is why numerous field tests, such as the Berg Balance Scale, and laboratory-based tests, particularly the Biodex Balance System, are commonly used in clinical settings. However, little evidence exists for the reliability and validity of such tests (Mancini & Horak, 2010). Concurrently, such tests are affected by various factors, such as age, gender, and other body characteristics that require specific reference values (Andreeva, et al., 2020). This allows the elimination of the contradicting research evidence of such field tests and clinically appropriate comparisons. Nevertheless, existing research shows gender differences in balance abilities (Chang & Do, 2015; Dallinga, Van Der Does, Benjaminse, & Lemmink, 2016; Muraki, et al., 2013), while some studies do not (Melam, Buragadda, Alhusaini, Ibrahim, & Kachanathu, 2014; Riva, et al., 2013). Therefore, the objective of this study was to establish and update normative data regarding healthy persons for the Biodex Balance System and to compare gender and limb performance.

Methods

Sample

The sample of participants in this cross-sectional design was selected from communities in the city of Johannesburg, South Africa. The sample was composed of 161 apparently healthy (n = 81 females; n = 80 males) adults aged between 18-55 years. Participants were excluded if they were obese (BMI >30 $kg.m^{-2}$) (Son, 2016), same family (parents or siblings to eliminate over-representation from a single family or household and eliminate bias) (Sajjadi & Paparella, 2008), or continuously active in competitive sport prior and upon the date of data collection (Zemková, 2014).

To further ensure the reliability and validity of the study, participants with diagnosed medical problems, either acute or chronic conditions, particularly neurological disorders (i.e., Meniere's disease, middle ear infection) (D'Silva, Lin, Staecker, Whitney, & Kluding, 2016; Meldrum, et al., 2012), pregnancy (Segal & Chu, 2015), or if taking any medication or drug substances that could potentially affect the results (De Groot, et al., 2013; Mahmoudzadeh, et al., 2020) were excluded from this study.

Prior to the commencement of the study, written informed consent was obtained from all participants to engage in the study. This study was approved by the Institutional Review Board of the University of Johannesburg (REC-01-123-2016).

Data collection

During data collection, initially, participants were assessed using a self-reported leg dominance questionnaire (van Melick, et al., 2017). This implies that participants had to identify the leg which is mostly utilised when kicking the ball to a maximum distance (Mahmoudzadeh, et al., 2021). The preprogrammed "Postural Stability Test" on the Biodex Balance System (Model 950-440, Biodex Medical Systems, Inc., Shirley, New York) was used to assess both static and dynamic balance (Cachupe, Shifflett, Kahanov, & Wughalter, 2001; Karimi, Ebrahimi, Kahrizi, & Torkaman, 2008; Parraca, et al., 2011). Balance ability was assessed using four different evidence-based protocols: (1) double-leg stable/static (level 12), (2) double-leg unstable/dynamic (level 8), (3) dominant and non-dominant, single-leg stable/static (level 12), and (4) dominant and non-dominant, single-leg unstable/dynamic (level 8) (Finn, Alvarex, Jett, Axtell, & Kemler, 1999). Foot placement was prescribed by the system's software according to each participant's height. Participants were provided three chances with one trial for familiarisation with the device and the test procedures prior to testing. The average score between the last two trials was recorded as the final score. The "Overall Stability Index" score was recorded as anterior-posterior, as well as left-to-right perturbations (Biodex Medical Systems, 2000). Previously, overall composite scores (intraclass correlation coefficients [ICC] ICC3,1 = 0.71, and minimal detectable change [MDC] = 1.21) have been found for the Biodex system showing moderate test-retest reliability. In addition, the Biodex overall Sway Index (SI) has previously shown acceptable reliability criterion validity (r = 0.52) (Peller, et al., 2023).

Statistical analysis

Descriptive statistics of the variables were presented as means±standard deviations and percentiles. Due to the heterogeneousness of the data, the Kruskal-Wallis and Mann-Whitney U tests were used to test for significant differences in balance abilities between males and females. The significance level was set at $p \leq .05$. Statistical analyses were performed using the Statistical Package for the Social Sciences ver. 26.0 (IBM Co., Armonk, NY, USA).

Results

Out of the 161 participants, only five were left-dominant (3.11%), with 156 being right-dominant (96.89%). While no significant differences were found in BMI between males and females (p=.296); however, males (n = 80) were reported as significantly older (p=.000), taller (p=.000), and heavier (p=.000) than females (n = 81) (Table 1).

Tables 2 and 3 present gender- and limb-specific normative data for healthy adults for the Biodex Balance System. Practically, these reference percentile values provide needed comparative data for sports medicine practitioners who use the Biodex Balance System in healthy adults.

Interestingly, females scored significantly better in double-leg static balance (p=.031) and double-leg dynamic balance (p=.002) when compared to males (Table 4). Moreover, females demonstrated a significantly better single-leg dynamic balance on both the left (p=.003) and right lower limbs (p=.013).

Table 1. Demographic characteristics of participants in each group

Variable	Females (*n* = 81)	Males (*n* = 80)	Significance (p-value)
Age (years)	32.86 ± 12.14	34.64 ± 11.12	.000*
Height (cm)	163.69 ± 5.51	175.25 ± 8.01	.000*
Body weight (kg)	64.16 ± 10.37	78.73 ± 10.36	.000*
BMI ($kg.m^{-2}$)	23.90 ± 3.45	25.61 ± 2.78	.296

Note. Data reported as means±standard deviations (SD). *: Statistically significant (p≤.05). cm: centimetres; kg: kilograms; BMI: body mass index; $kg.m^{-2}$: kilograms per square metre. *Males (n = 80) were reported as significantly older (p=.000), taller (p=.000), and heavier (p=.000) than females (n = 81).

Table 2. Limb-specific normative data for healthy females for the Biodex Balance System

Percentile	10	20	30	40	50	60	70	80	90
Stable conditions									
Double-leg stable	.200	.200	.300	.300	.400	.400	.400	.500	.600
Single-leg stable (left)	.600	.700	.800	.800	1.000	1.020	1.200	1.460	2.080
Single-leg stable (right)	.600	.700	.800	.800	.900	1.100	1.200	1.400	1.800
Unstable conditions									
Double-leg unstable	.400	.500	.500	.600	.600	.700	.800	.800	.900
Single-leg unstable (left)	.500	.600	.700	.800	.900	1.000	1.100	1.200	1.300
Single-leg unstable (right)	.500	.600	.700	.800	.900	1.000	1.100	1.200	1.400

Table 3. Limb-specific normative data for healthy males for the Biodex Balance System

Percentile	10	20	30	40	50	60	70	80	90
Stable conditions									
Double-leg stable	.200	.300	.330	.400	.400	.500	.500	.600	.700
Single-leg stable (left)	.600	.620	.700	.800	.900	.900	1.000	1.200	1.500
Single-leg stable (right)	.600	.700	.700	.800	.900	1.000	1.100	1.200	1.400
Unstable conditions									
Double-leg unstable	.500	.520	.600	.700	.800	.800	.900	.980	1.000
Single-leg unstable (left)	.700	.700	.800	.900	1.000	1.160	1.300	1.400	1.500
Single-leg unstable (right)	.600	.800	.830	.900	1.000	1.100	1.200	1.300	1.400

Table 4. Gender and limb effects on adult normative data for the Biodex Balance System

Parameter	Females (*n* = 81)	Males (*n* = 80)	Significance (p-value)
Stable conditions			
Double-leg stable	0.415 ± 0.24	0.473 ± 0.27	.031*
Single-leg stable (left)	1.159 ±0 .67	0.969 ± 0.45	.088
Single-leg stable (right)	1.111 ± 0.63	0.956 ± 0.42	.136
Unstable conditions			
Double-leg unstable	0.660 ± 0 .23	0.765 ± 0.23	.002*
Single-leg unstable (left)	0.893 ± 0 .33	1.069 ± 0.35	.003*
Single-leg unstable (right)	0.916 ± 0.35	1.051 ± 0.36	.013*

Note. Data reported as means±standard deviations (SD). *: Statistically significant (p≤.05.)

Discussion and conclusions

Although there are studies in the literature that provide reference data for balance performance, research is limited regarding gender-specific normative data, especially for the Biodex Balance System. Further, much data focused on existing conditions but failed to investigate healthy adults with an aim to the prevention of conditions and/or injuries related to poor balance. This dearth of reference data is especially apparent for specific limbs during static and dynamic conditions. The results of this study present updated normative data for the Biodex Balance System regarding healthy persons necessitated by recent revisions to the Biodex Balance System (Riemann & Davies, 2013). In addition to this reference data, the present study also demonstrates that healthy females performed better on double-leg static balance, double-leg dynamic balance, and single-leg dynamic balance on both the left and right legs when compared to males indicating the need to use gender-stratified normative data when using the Biodex Balance System to interpret double- and single-leg, static and dynamic balance test performance.

While some research suggests that no differences exist in static balance between males and females (Melam, et al., 2014; Riva, et al., 2013), the present study supports those findings that females perform better than males on static balance tests (Dorneles, Pranke, & Mota 2013; Howell, Hanson, Sugimoto, Stracciolini, & Meehan, 2017). However, it must be noted that in this study, males and females performed equally on static single-leg balance. As such, this study's findings support the proposition that females tend to have a lower postural sway than males, therefore allowing them to have better postural control and balance than males (Dorneles, et al., 2013). It may be that the methodological differences, such as the variety of instrumentation, design, and populations used, may explain the mixed results reported. Despite this, these findings add to existing knowledge in that both the older and revised versions of the Biodex Systems, investigations are conspicuous in their absence when considering gender differences, especially in single-leg balance performance (Riemann & Davies, 2013).

This increased balance performance in females can be explained by the inverted pendulum model of balance and may relate to them having a lower centre of mass and thus a lower centre of gravity, especially under more challenging unstable conditions (Schulleri, Johannsen, Michel, & Lee, 2022). Specifically, females have a lower height effectively reducing their centre of gravity when compared to their male counterparts (Alonso, et al., 2015; Alter, 2004; Rivas & Andries, 2007). Further, not only do females have a reduced centre of gravity, but this lowered centre is supported by a larger pelvis, allowing for a greater relative distance between the two femoral heads, thus increasing the relative width of the base of support (Rivas & Andries, 2007). Specifically, the reduction in the male's base of support, especially during single-leg balance testing results in frequent compensatory movements (Riemann & Davies, 2013).

Another gender-specific anthropometric factor that could affect balance relates to trunk-cephalic length, especially during upright stance. In this regard, the longer torsos and broader shoulders of males increase the amount of postural sway (Alonso, Brech, Bourquin, & Greve, 2011). In addition, the increased mass of males, when compared to females, also leads to increased postural instability (Greve, Cug, Dulgeroglu, Brech, & Alonso, 2013; Hue, et al., 2007). Of particular importance for postural testing, and especially postural training, are those taller individuals, whether male or female, who may require additional gastrocnemius muscular fitness (i.e., flexibility, strength, and muscle endurance, etc.) training, since gastrocnemius muscle activity is found to be increased in taller individuals during standing, while ankle stiffness is inversely related to balance performance (Alonso, et al, 2011, 2015).

Several other explanations for differences in gender balance performance have been suggested, such as differences in male and female activity (Thomas & French, 1985). However, this study did not include the levels of physical or athletic activity as part of the inclusion criteria. It is for this reason that further investigation is necessitated to determine the mechanisms responsible for differences in male and female balance performance on the Biodex Balance System, to fully interpret balance test scores.

Compared with the limb differences, the results of this investigation revealed compelling gender-specific differences when assessing balance using the Biodex Balance System in healthy adults. Posturography normative data in this population is crucial for the surveillance of postural balance and for the timely diagnosis of any dysfunction. We provide gender- and limb-based normative values for the Biodex Balance System, which will likely be helpful when using this technology to determine individual capabilities that could help athletes and coaches identify areas in need of improvement and can be used in goal setting (Semin, et al., 2008). This data could also be used to identify lower percentiles that can be used as a "warning signal" to conduct additional tests to identify possible independence issues related to ADLs, fall and incapacity avoidance, residual injury impairment, and future injury risk in sports medicine testing and rehabilitation.

References

Alonso, A.C., Brech, G.C., Bourquin, A.M., & Greve, J.M.D.A. (2011). The influence of lower-limb dominance on postural stability. *Sao Paulo Medical Journal*, *129*(6), 410-413. https://doi.org/10.1590/S1516-31802011000600007

Alonso, A.C., Mochizuki, L., Luna, N.M.S., Ayama, S., Canonica, A.C., & Greve, J.M.D.A. (2015). Relation between the sensory and anthropometric variables in the quiet standing postural control: Is the inverted pendulum important for the static balance control. *BioMed Research International*, *25*(2), 209-214. https://doi.org/10.1155/2015/985312

Alter, M.J. (2004). *Science of flexibility*. Champaign, IL: Human Kinetics.

Andreeva, A., Melnikov, A., Skvortsov, D., Akhmerova, K., Vavaev, A., Golov, A., Draugelite, V., Nikolaev, R., Chechelnickaia, S., Zhuk, D., Bayerbakh, A., Nikulin, V., & Zemková, E. (2020). Postural stability in athletes: The role of age, sex, performance level, and athlete shoe features. *Sports*, *8*, 89. https://doi.org/10.3390/sports8060089

Bahari, F., Naghdi, N., Sheikh, M., & Shaw, B.S. (2021). Effect of physical exercise on muscle strength, static and dynamic balance and resiliency in women with multiple sclerosis. *South African Journal for Research in Sport, Physical Education and Recreation*, *43*(1), 1-11.

Biodex Medical Systems, Inc. (2000). *Biodex Balance System SD. Clinical Resource Manual*. New York: Shirley.

Cachupe, W.J.C., Shifflett, B., Kahanov, L., & Wughalter, E.H. (2001). Reliability of Biodex Balance System measures. *Measurement in Physical Education and Exercise Science*, *5*(2), 97-108. https://doi.org/10.1207/S15327841MPEE0502_3

Chang, V.C., & Do, M.T. (2015). Risk factors for falls among seniors: Implications of gender. *American Journal of Epidemiology*, *181*(7), 521-531. https://doi.org/10.1093/aje/kwu268

Dallinga, J.M., Van Der Does, H.T., Benjaminse, A., & Lemmink, K.A. (2016). Dynamic postural stability differences between male and female players with and without ankle sprain. *Physical Therapy in Sport*, *17*(1), 69-75. https://doi.org/10.1016/j.ptsp.2015.05.002

De Groot, M.H., Van Campen, J.P.C.M., Moek, M.A., Tulner, L.R., Beijnen, J.H., & Lamoth, C.J.C. (2013). The effects of fall-risk-increasing drugs on postural control: A literature review. *Drugs and Aging*, *30*(11), 901-920. https://doi.org/10.1007/s40266-013-0113-9

Dorneles, P.P., Pranke, G.I., & Mota, C.B. (2013). Comparison of postural balance between female and male adolescents. *Fisioterapia e Pesquisa*, *20*(3), 210-214. https://doi.org/10.1590/S1809-29502013000300003

D'Silva, L.J., Lin, J., Staecker, H., Whitney, S.L., & Kluding, P.M. (2016). Impact of diabetic complications on balance and falls: Contribution of the vestibular system. *Physical Therapy*, *96*(3), 400-409. https://doi.org/10.2522/ptj.20140604

Finn, J.A., Alvarex, M.M., Jett, R.E., Axtell, R.S., & Kemler, D.S. (1999). Biodex Balance Assessment among subjects of disparate balancing abilities. In *Clinical Resource Manual*. New York: Biodex Medical Systems, Inc. https://doi.org/10.1097/00005768-199905001-01209

Fourie, M., Gildenhuys, G.M., Shaw, I., Shaw, B.S., Toriola, A.L., & Goon, D.T. (2012). Effects of a mat Pilates programme on muscular strength and endurance in elderly women. *African Journal for Physical, Health Education, Recreation and Dance*, *18*(2), 296-304.

Greve, J.M., Cug, M., Dulgeroglu, D., Brech, G., & Alonso, A.C. (2013). Relationship between anthropometric factors, gender, and balance under unstable conditions in young adults. *BioMed Research International*, *2013*, article ID 850424. https://doi.org/10.1155/2013/850424

Halvarsson, A., Dohrn, I.M., & Ståhle, A. (2015). Taking balance training for older adults one step further: The rationale for and a description of a proven balance training program. *Clinical Rehabilitation*, *29*(5), 417-425. https://doi.org/10.1177/0269215514546770

Howell, D.R., Hanson, E., Sugimoto, D., Stracciolini, A., & Meehan, W.P. (2017). Assessment of the postural stability of female and male athletes. *Clinical Journal of Sport Medicine*, *27*(5), 444-449. https://doi.org/10.1097/JSM.0000000000000374

Hue, O., Simoneau, M., Marcotte, J., Berrigan, F., Doré, J., Marceau, P., Marceau, S., Tremblay, A., & Teasdale, N. (2007). Body mass is a strong predictor of postural stability. *Gait and Posture*, *26*(1), 32-38. https://doi.org/10.1016/j.gaitpost.2006.07.005

Karimi, N., Ebrahimi, I., Kahrizi, S., & Torkaman, G. (2008). Evaluation of postural balance using the Biodex Balance System in subjects with and without low back pain. *Pakistan Journal of Medical Sciences*, *24*(3), 372-377.

Mahmoudzadeh, A., Ansari, N.N., Naghdi, S. Sadeghi-Demneh, E., Motamedzadeh, O., Shaw, B.S., Shariat, A., & Shaw, I. (2020). Effect of ankle plantar flexor spasticity level on balance in patients with stroke: Protocol for a cross-sectional study. *JMIR Research Protocols*., *9*(8), e16045. https:doi.org/10.2196/16045

Mahmoudzadeh, A., Nakhostin-Ansari, N., Naghdi, S., Ghasemi, E., Shaw, B.S., & Shaw, I. (2021). Role of spasticity severity on the balance of post-stroke patients. *Frontiers in Human Neuroscience*, *15*. https://doi.org/10.3389/fnhum.2021.783093

Mancini, M., & Horak, F.B. (2010). The relevance of clinical balance assessment tools to differentiate balance deficits. *European Journal of Physical and Rehabilitation Medicine*, *46*(2), 239-248.

McKeon, P.O., & Hertel, J. (2008). Systematic review of postural control and lateral ankle instability, part I: Can deficits be detected with instrumented testing? *Journal of Athletic Training*, *43*(3), 293-304. https://doi.org/10.4085/1062-6050-43.3.293

Melam, G.R., Buragadda, S., Alhusaini, A., Ibrahim, A.I., & Kachanathu, S.J. (2014). Gender differences in static and dynamic postural stability parameters in community dwelling healthy older adults. *Middle-East Journal of Scientific Research*, *22*(9), 1259-1264.

Meldrum, D., Herdman, S., Moloney, R., Murray, D., Duffy, D., Malone, K., French, H., Hone, S., Conroy, R., & Mcconn-Walsh, R. (2012). Effectiveness of conventional versus virtual reality based vestibular rehabilitation in the treatment of dizziness, gait and balance impairment in adults with unilateral peripheral vestibular loss: A randomised controlled trial. *BMC Ear, Nose and Throat Disorders*, *12*(3), 139-142. https://doi.org/10.1186/1472-6815-12-3

Muraki, S., Akune, T., Ishimoto, Y., Nagata, K., Yoshida, M., Tanaka, S., Oka, H., Kawaguchi, H., Nakamura, K., & Yoshimura, M. (2013). Risk factors for falls in a longitudinal population-based cohort study of Japanese men and women: The ROAD Study. *Bone*, *52*(1), 516-523. https://doi.org/10.1016/j.bone.2012.10.020

Parraca, J.A., Olivares, P.R., Carbonell-Baeza, A., Aparicio, V.A., Adsuar, J.C., & Gusi, N. (2011). Test-retest reliability of Biodex Balance SD on physically active old people. *Journal of Human Sport and Exercise*, *6*(2), 444-451. https://doi.org/10.4100/jhse.2011.62.25

Peller, A., Garib, R., Garbe, E., Komforti, D., Joffe, C., Magras, A., Trapuzzano, A., Stock, M.S., Dawson, N.T. (2023) Validity and reliability of the NIH Toolbox® Standing Balance Test as compared to the Biodex Balance System SD. *Physiotherapy Theory and Practice*, *39*(4), 827-833. https://10.1080/09593985.2022.2027584

Riemann, B.L., & Davies, G.J. (2013). Limb, sex, and anthropometric factors influencing normative data for the Biodex Balance System SD Athlete Single Leg Stability Test. *Athletic Training and Sports Health Care*, *5*(5), 224-232. https://doi.org/10.3928/19425864-20130827-02

Riva, D., Mamo, C., Fanì, M., Saccavino, P., Rocca, F., Momenté, M., & Fratta, M. (2013). Single stance stability and proprioceptive control in older adults living at home: Gender and age differences. *Journal of Aging Research*, *2013*(1), 1-14. https://doi.org/10.1155/2013/561695

Rivas, R.C., & Andries, J.O. (2007). Sexual dimorphism and its implications on the performance and planning of women's sports. *Movement and Perception*, *7*(10), 126-148.

Sajjadi, H., & Paparella, M.M. (2008). Meniere's disease. *The Lancet*, *372*(9636), 406-414. https://doi.org/10.1016/S0140-6736(08)61161-7

Schulleri, K.H., Johannsen, L., Michel, Y., & Lee, D. (2022). Sex differences in the association of postural control with indirect measures of body representations. *Scientific Reports*, *12*, 4556. https://doi.org/10.1038/s41598-022-07738-8

Segal, N.A., & Chu, S.R. (2015). Musculoskeletal anatomic, gait and balance changes in pregnancy and risk for falls. In Fitzgerald, C.M. & Segal, N.A. (Eds.), *Musculoskeletal health in pregnancy and postpartum: An evidence-based guide for clinicians*. Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-14319-4_1

Semin, K., Stahlnecker IV, A.C., Heelan, K., Brown, G.A., Shaw, B.S., & Shaw, I. (2008). Discrepancy between training, competition and laboratory measures of maximum heart rate in NCAA division 2 distance runners. *Journal of Sports Science and Medicine*, *7*(4): 455-460.

Shariat, A., Najafabadi, M.G., Ghannadi, S., Nakhostin-Ansari, A., Hakakzadeh, A., Shaw, B.S., Ingle, L., & Cleland, J.A. (2022). Effects of aquatic therapy on balance in older adults: A systematic review and meta-analysis. *European Geriatric Medicine*, *13*, 381-393. https://doi.org/10.1007/s41999-021-00577-2

Son, S.M. (2016). Influence of obesity on postural stability in young adults. *Osong Public Health and Research Perspectives*, *7*(6), 378-381. https://doi.org/10.1016/j.phrp.2016.10.001

Thomas, J.R., & French, K.E. (1985). Gender differences across age in motor performance: A meta-analysis. *Psychological Bulletin*, *98*(2), 260-282. https://doi.org/10.1037/0033-2909.98.2.260

van Melick, N., Meddeler, B.M., Hoogeboom, T.J., Nijhuis-van der Sanden, M.W.G., & van Cingel, R.E.H. (2017). How to determine leg dominance: The agreement between self-reported and observed performance in healthy adults. *PLoS One*, *12*(12), e0189876. https://10.1371/journal.pone.0189876

Zemková, E. (2014). Sport-specific balance. *Sports Medicine*, *44*(5), 579-590. https://doi.org/10.1007/s40279-013-0130-1

Submitted: August 26, 2022
Accepted: June 12, 2023
Published Online First: October 20, 2023

Correspondence to:
Ina Shaw, Ph.D.
School of Sport, Rehabilitation and Exercise Sciences
University of Essex
Wivenhoe Park, Colchester, Essex, United Kingdom
E-mail: i.shaw@essex.ac.uk

Acknowledgements

The authors declare that there is no conflict of interest. The authors would like to acknowledge the contributions made by the Non-Communicable Disease Intervention Research Unit (NCDIRU), USA.