VU Research Portal

The degree of misjudgment between perceived and actual gait ability in older adults.

Kluft, N.; van Dieen, J.H.; Pijnappels, M.A.G.M.

published in

Gait and Posture

2017

DOI (link to publisher)

[10.1016/j.gaitpost.2016.10.019](https://doi.org/10.1016/j.gaitpost.2016.10.019)

[Link to publication in VU Research Portal](#)

citation for published version (APA)

Kluft, N., van Dieen, J. H., & Pijnappels, M. A. G. M. (2017). The degree of misjudgment between perceived and actual gait ability in older adults. *Gait and Posture*, 51, 275-280. <https://doi.org/10.1016/j.gaitpost.2016.10.019>

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:

vuresearchportal.ub@vu.nl

The degree of misjudgment between perceived and actual gait ability in older adults

Nick Kluit, Jaap H. van Dieën, Mirjam Pijnappels *

MOVE Research Institute Amsterdam, Department of Human Movement Sciences, VU Amsterdam, Van der Boechorststraat 7–9, 1081BT Amsterdam, The Netherlands

ARTICLE INFO

Article history:

Received 21 April 2016

Received in revised form 20 October 2016

Accepted 24 October 2016

Keywords:

Accidental falls

Self efficacy

Locomotion

Physical capacities

Decision-making

ABSTRACT

Successful execution of motor tasks requires an integration of the perception of one's physical abilities and the perception of the task itself. Physical and cognitive decline associated with ageing may lead to misjudgments of these perceived and actual abilities and possibly to errors that may lead to balance loss. We aimed to directly quantify the degree to which older adults misjudge their actual gait ability. Twenty-seven older adults participated and were instructed to walk on a narrow path projected on a treadmill. We tested two paradigms to estimate the participants' perceived gait ability: a path width manipulation, in which participants had to indicate the smallest path width that they could walk on without stepping outside or losing balance (at given speed), and a treadmill speed manipulation, in which they had to indicate the maximum speed that they could use at a given path width. We determined their actual ability as the probability of stepping inside the path over a range of path widths and speeds. The path width paradigm seemed suitable for evaluating self-perception of actual gait ability and revealed that participants appeared to show a range of misjudgment towards either over- or underestimating their actual abilities. Better abilities appeared not associated with better judgment. Direct quantification of the degree of misjudgment provides insight in the interplay between cognition and physical abilities and can be of added value towards prevention of falls and promotion of healthy ageing.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

For optimal motor performance, we need to predict the results of our motor actions in different circumstances. This predictive ability requires estimation of one's own physical abilities. Although this knowledge is not always perfect [15], in most cases we are nevertheless able to make an educated guess whether execution of a planned task can be performed successfully. Already at a young age, infants learn whether or not to move down a slope based on their locomotor abilities [1]. At the other side of the age spectrum, physical decline [28,24,21] requires accompanying adjustment of the perception of these abilities to select the appropriate motor strategy in view of the motor task requirements. This adjustment might even be all the more challenging due to the age-related brain changes such as reduced neural plasticity [25,16]

and cognitive functioning [21]. Erroneous perception of one's own physical abilities or of the task requirements could lead to excessive risk-taking on the one hand [3], or needless avoidance of activities on the other hand [5].

Almost one-third of the older adults misjudged their physiological fall risk [4]. Age-related perceptual (mis)judgement of physical abilities has further been studied in gait related tasks. For example in aperture crossing, older adults rotate their shoulders more compared to young adults [8,9] and in stair climbing, older participants appear more likely to choose a step height which matches their maximum achievable step height than their younger peers [14], suggesting that estimates on physical capacities are adjusted with ageing. Nevertheless, 20% of the observed older persons overestimated their maximum step height, whereas 10% underestimated their maximum achievable step height [14]. Sakurai et al. [19] compared the estimated and actual height for stepping over a bar and found that 18% of the older adults overestimated the bar height that they could overstep. These studies mainly tested perception of abilities limited by physical dimensions, such as shoulder width or leg length.

* Corresponding author.

E-mail addresses: n.kluit@vu.nl (N. Kluit), j.van.dieen@vu.nl (J.H. van Dieën), m.pijnappels@vu.nl (M. Pijnappels).

The relation between physical ability and perceived ability regarding balance control has been studied by Butler and co-workers [3] in plank crossing. They investigated the behavioural risk that older adults were willing to take by comparing individuals' selected plank width with the probability to make errors on this width measured during over ground walking. They found that persons whose behavioural risk matched their physical ability were less likely to experience a fall in the forthcoming year than their peers who took higher risks [3]. However, participants chose a plank to cross but were not actually allowed to cross it. The chosen plank width was compared with the stepping accuracy on an 18-cm wide path at ground level. Perceptual judgment may in this design be affected by plank height or length, and for actual ability ceiling effects may have occurred given the fixed path width.

We aimed to directly quantify the agreement of older adults' perceptual judgment and their actual ability in a daily life task (i.e., walking). We propose two paradigms of testing actual gait ability: a path width manipulation and a speed manipulation and asked participants to indicate the smallest path width (at given speed) and maximum speed (at given path width) at which they believed they could accurately perform, i.e., walk without stepping outside the path or losing balance. These manipulations were expected to affect step accuracy during gait. Narrowing the path width reduces the base of support and a more strict control of the centre of mass movement is needed to successfully complete the task [2,20]. Older adults have also been shown to decrease gait speed when walking on a narrow path [20,6], suggesting that more time is needed in narrow base walking for more strict control of foot placement. For both path width and speed manipulations, the perceived and actual abilities can be determined and compared to provide insight into the older adult's degree of misjudgment. Since one-third of older adults misjudges their fall risk [4], we expected no strong correlation between the perceived and actual gait ability. Furthermore, since sport experts are more accurate at judging their capabilities than their less expert peers [26,27], we hypothesised that older adults with better gait performance levels judge their actual abilities better than those performing less.

2. Methods

2.1. Subjects

Twenty-seven older adults (74.4 SD 5.6 years, 16 females) participated. Persons who had a mini mental state examination (MMSE) score of 24 or lower, were not able to walk continuously and without walking aid for 10 min, reported any musculoskeletal or neurological impairments or major trauma in the last year, or took medication which could have affected their gait stability, were excluded from participation. All participants signed an informed consent, which was approved by the local research ethics committee (#2015-50).

2.2. Protocol

Before the gait ability test, we assessed participants' self-efficacy [13], using the Dutch version of the Falls Efficacy Scale International (FES-I, [29]) and their physical capacities by measuring grip strength (A5401-Digital Hand Grip Strength Dynamometer, Take, Niigata, Japan) and knee extension strength (MicroFET 2, Hoggan Health Industries, Draper, UT).

Participants were familiarised with walking on a large, motor-driven treadmill at a speed of 1.11 m/s (S-Mill, Forcelink, Culemborg, The Netherlands; length $\times$ width: 4 $\times$ 3 m) for at least 3 min or longer if considered necessary by the participant or experimenter. A projector (CP-X5022WN, Hitachi, Tokyo, Japan)

projected in the walking direction on the treadmill a visual path; a yellow rectangle of which the width could be varied while the virtual path length was always 20 m, irrespective of speed. Participants wore a safety harness, attached by ropes to the ceiling. First, the self-perceived path width performance ($Width_{perc}$) was determined by instructing the participants to indicate the narrowest path width they perceived they could walk on without stepping outside the path's boundaries, at the speed they experienced during the familiarisation period. This procedure was done on a stationary treadmill, by scrolling the scroll-wheel of a handheld computer mouse to adjust the width of the projected path, and repeated four times and randomised in two directions, by broadening a path starting at 0.05 m and narrowing a path starting at 0.50 m. Secondly, the actual path width was determined by subjecting the participants to 3 repetitions of 5 randomised paths widths (0.120, 0.144, 0.160, 0.178, 0.200 m) while walking at a speed of 1.11 m/s. There was at least 10 m without projection before a new path was presented. Thirdly, the participants walked at 1.11 m/s, and a 0.16 $\times$ 0.16 m square was projected 1.50 m in front of them for 10 seconds. Then the projection disappeared and the treadmill simultaneously switched to a self-paced mode. This mode allowed participants to control their own gait speed by speeding up or slowing down. The algorithm the treadmill obeyed was conform Eq. (1) ([23] for details). This equation is based on a standard PD-controller and controls the belt using participant's position (x) and gait speed ($\dot{x}$). The parameters K_x and $K_{\dot{x}}$ are respectively a position-gain and a speed-gain, and were set at 0.6 and 1.2.

$$\ddot{x} = K_x \cdot \Delta x - K_{\dot{x}} \cdot \dot{x} \cdot \Delta x \quad (1)$$

Participants were instructed to adjust their speed as soon as the square disappeared and indicate the fastest speed they believed they could walk without stepping outside the path at the previously indicated path width. Prior to this speed manipulation, participants were given the opportunity to familiarise again for at least 3 min with the self-paced mode of the treadmill. The mean speed of four repetitions was used to determine the self-perceived speed (v_{perc}). Finally, we determined the actual speed (v_{act}) by asking the participants to walk on paths of a fixed width of 0.16 m for 3 repetitions at 5 different speeds (0.83, 0.97, 1.11, 1.25, 1.39 m/s). The order of speeds was randomised over subjects and for each speed, the participants performed 3 paths before the speed changed. In all experimental testing participants walked without any assistive walking device.

2.3. Data acquisition and analysis

Feet and pelvis kinematics were measured using an OptoTrak motion capture system (Northern Digital Inc., Ontario, Canada). Three rigid clusters with three infrared light emitting diodes each, were placed on the participant's heels and lower back and were captured by a 2 $\times$ 3 camera array. The feet were considered as rigid segments and a pointer was used to indicate the outer boundaries of the shoe (Fig. 1) as well as the position of the projected path in space. Separate pointer recordings were combined to express the projected path and foot markers in global coordinates [30]. Gait events (toe-offs and heel strikes) were automatically detected from the kinematic data [12], and visually checked. From these boundaries (Fig. 1), the positions of the middle of the foot at mid-stance were determined. A Gaussian probability curve was fitted to the mediolateral mid-stance foot position data. This enabled the computation of the probability of successfully stepping with the entire foot inside the projected path ($P(path)$, Fig. 1) according to Butler et al. [3]. Following this calculation, $P(path)$ depended on the combination of step width, step width variability, and the mean

Fig. 1. A Gaussian probability curve was fitted on the mediolateral positions of the middle of the foot. The middle of the foot was calculated from the pointed positions indicated in the box in the figure. The area underneath this curve and which is covered by the virtual path is the probability of success and denoted by $P(path)$. The hypothetical path width which covers 90% of the probability curve was computed and coined $Width_{act}$. The peak of the probability curve represents the average mediolateral foot position and is not in the middle of the path per se. These procedures were adapted from a study by Butler and co-workers [3].

mediolateral foot position. For our proposed manipulation to be useful to determine the degree of misjudgment, $P(path)$ had to be related to path width or speed, which was the case for the path width but not for the speed manipulation. Therefore only for the path width manipulation, the best actual performance was calculated ($Width_{act}$). This was defined as the path width that would contain 90% of all steps based on the distribution of step widths in the best trial ($Width_{act}$); Fig. 1). Subsequently, the association between $Width_{perc}$ and $Width_{act}$ was calculated and the degree of misjudgment was determined by the vertical distance to the identity line for this association. A negative score indicated underestimation of one's ability, while a positive score indicated overestimation. Since strength and FES-I score are indicative for respectively actual and perceived ability, we used these measures to validate the perceived and actual ability components of the degree of misjudgment. Analyses were performed using MATLAB R2015b (Mathworks, Natick, MA).

2.4. Statistical analysis

First, to evaluate the effects of manipulations on $P(path)$, step width, and step width variability, repeated measures analysis of variance (ANOVA) was used. Mauchly's test showed a violation of sphericity for $P(path)$ ($W = 0.226$, $p < 0.001$) and step width variability ($W = 0.442$, $p = 0.017$) for the path width manipulation, and step width ($W = 0.379$, $p = 0.038$) for the speed manipulation, thus for these measures a Greenhouse Geiser correction ($P(path)$: $\epsilon = 0.572$, step width variability: $\epsilon = 0.725$, step width: $\epsilon = 0.744$)

was applied. Post-hoc paired t -tests with Bonferroni adjustment were used on significant main effects. Further analyses were restricted to the path width manipulation as only this significantly affected gait accuracy.

The scores on the FES-I were compared with the perceived ability using a Spearman's rank correlation rho with Monte-Carlo resampling. This test was used because the scores on the FES-I were not normally distributed ($W = 0.801$, $p < 0.001$). The consistency over the four repetitions of indicating self-perceived ability ($Width_{perc}$) was assessed using an intraclass correlation coefficient (ICC).

To investigate associations between $Width_{act}$ and physical capacities (knee extension strength and grip strength) or $Width_{perc}$, linear regression analysis was used for knee extension strength and a Spearman's rank correlation rho with Monte-Carlo resampling was used for grip strength and for $Width_{perc}$ as these were not normally distributed (grip strength: $W = 0.918$, $p = 0.035$, $Width_{perc}$: $W = 0.922$, $p = 0.030$).

Finally, to test whether the degree of judgment was dependent on the actual ability ($Width_{act}$) a Spearman's rank correlation rho with Monte-Carlo resampling was used because the absolute degree of misjudgment was not normally distributed ($W = 0.876$, $p = 0.004$).

Statistical software (R, version 3.1.1, R Core Team, <http://www.r-project.org/>) was used to perform the statistical analysis. Additionally, the coin package [11] was used for the implementation of the Monte-Carlo resampling procedure. For all statistical testing, the level of significance was set at 0.05.

3. Results

$P(path)$ was on average 0.80 ± 0.36 over all path widths and 0.86 ± 0.10 over all speeds (Fig. 2 and Table 1). Repeated measures ANOVA revealed a main effect of path width on $P(path)$ ($F(2.29, 59.51) = 24.779$, $p < 0.001$) and on step width ($F(4, 96) = 11.513$, $p < 0.001$). Post-hoc analysis showed that $P(path)$ values on the narrowest and broadest path widths were significantly different from all other path widths (Fig. 2a). Step width on the narrowest path significantly differed from the three most broad paths, and the step width on the broadest path width was significantly wider

Table 1

Descriptive statistics of outcome measures. Prevalence with percentage of sample (N(%)) or mean values with standard deviation (SD) are shown (mean(SD)). When a measure is not normally distributed the median and interquartile range (IQR) are given, indicated by the square brackets (median[IQR]).

Descriptives			
Age	74.4	(5.64)	years
Medication (≥ 4 different medicines)	6	(22%)	persons
Higher educated participants	16	(59%)	persons
Fallers (≥ 2 falls in the past year)	6	(22%)	persons
Falls in the past year	1	[1]	falls
MMSE	28	[2]	points
FES-I	18	[3.75]	points
Grip strength	290	[130]	N
Knee extension force	322	(76)	N
Body mass index	26.1	(3.7)	kg/m ²
Path width manipulation			
$Width_{perc}$	0.24	[0.17]	m
$Width_{act}$	0.16	(0.056)	m
$P(path)$	0.80	(0.13)	
Speed manipulation			
v_{perc}	1.35	(0.23)	m/s
$P(path)$	0.86	(0.10)	
Degree of misjudgment			
Total	-0.07	(0.105)	m
Absolute	0.07	[0.110]	m

Fig. 2. Probability of stepping inside the path ($P(path)$) versus the path width and speed manipulation. (a) Mean $P(path)$ on the path width manipulation (error bars represent standard deviations), which appeared affected by path width. (b) Mean $P(path)$ on the different speeds, which was not affected by speed. (c) Mean step width versus path width on a fixed speed (1.11 m/s). (d) Mean step width versus speed with fixed path width (0.160 m). (e) Mean step width variability versus path width. (f) Mean step width variability versus speed. Significant main differences are indicated by diamonds ($p < 0.05$). Post-hoc differences between adjacent levels ($p < 0.05$) are indicated by asterisks.

from those on the other paths except 0.160 m (Fig. 2c). $P(path)$ was not significantly affected by speed ($F(4,96) = 1.377$, $p = 0.248$, Fig. 2b).

ICCs showed that the test–retest reliability of testing $Width_{perc}$ was fairly high (ICC = 0.877). However, this perceived ability estimate ($Width_{perc}$) was not associated with the score on the FES-I ($\rho = 0.063$, $p = 0.750$).

Actual ability ($Width_{act}$) was negatively correlated with knee extension strength ($F(1,25) = 13.460$, $p = 0.001$, $R^2 = 0.350$, Fig. 3a), but was not associated with grip strength ($\rho = -0.142$, $p = 0.479$, Fig. 3b).

No significant association was found between $Width_{perc}$ and $Width_{act}$ ($\rho = 0.310$, $p = 0.115$, Fig. 4a), indicating no relation between perceived and actual ability. The scatter plot of $Width_{perc}$ and $Width_{act}$ also clearly shows different degrees of misjudgment between participants.

A Shapiro–Wilk’s test of normality showed that the degree of misjudgment was approximately normally distributed ($W = 0.961$, $p = 0.397$, Fig. 4b), with a skewness of -0.543 ($SE_{skew} = 0.448$) and a kurtosis of -0.319 ($SE_{kurt} = 0.872$).

Performance did not influence on the absolute degree of misjudgment ($\rho = -0.088$, $p = 0.650$), indicating that judgment of gait accuracy was not dependent on actual ability.

4. Discussion

A narrower path width led to more errors than a wider path width, as expected but gait accuracy was not influenced by speed (Fig. 2b). Although we expected accuracy to decrease with increasing speed, path width and path width variability did not change over speeds on the group level. Possibly, this can be explained by a quadratical relation between step width and walking speed (i.e., following a U-shape) [10], where the smallest step width occurs near the preferred walking speed. For the speed manipulation, a fixed range of speeds was imposed, and thus for each participant different relative speeds in terms of preferred walking speed might have effaced the individual effects of step width and step width variability and therefore accuracy. Relating gait accuracy to preferred walking speed could help understand

Fig. 3. Peak strength versus the path width with a 90% chance of success ($Width_{act}$). (a) Participants with a higher normalised knee extension strength were more likely to have a smaller $Width_{act}$, this effect was significant ($F(1,25) = 13.5$, $p = 0.001$). (b) Generated grip strength versus $Width_{act}$.

Fig. 4. Degree of misjudgment. (a) The perceived and actual ability displayed for every participant (circles). The degree of misjudgment was calculated by subtracting the $Width_{perc}$ from the $Width_{act}$. (b) Degree of misjudgment. Perfect agreement of the two measures will lead to no misjudgment and a score of zero. A positive score inclines overestimating, where a negative score inclines underestimating.

this relationship, however preferred walking speed might be influenced by one's perceived ability.

The two components of the degree of misjudgment were compared to FES-I and the strength measures to explore the validity of these components. The significant correlation between knee extension force and $Width_{act}$ suggests that $Width_{act}$ is a suitable measure of the participants' actual capacities. Moreover, Shin et al. [22] showed that wider steps were related to lower leg strength, suggesting that step width reflects one's actual ability. $Width_{perc}$ was not related to FES-I, which might suggest that $Width_{perc}$ was not a suitable measure, yet it can be questioned whether FES-I was an appropriate and sensitive variable to verify self-perception of motor capacities in our sample. Despite a large range in knee extension strength in our sample, and grip strength values within normal bounds of the general population [7], the range for FES-I scores was only 16–27 out of a maximum score of 64, which was lower than the mean score of 28 points in a larger sample of the Dutch population [13]. ICC values showed that participants were very consistent in indicating their perceived abilities over the four repetitions, suggesting that participants had a well defined perception of what they thought they were able to accomplish, although this could also be a consequence of a tendency of participants to be consistent [18].

We expected that participants with good physical abilities to be more accurate in their judgment than those with low abilities. Although not studied in gait, Williams and Ericsson [26] reviewed several perceptual-cognitive experiments and argued that experts had better decision making skills than their less expert peers. In contrast, we found no evidence for this in our results. Given our inclusion criteria, all our participants had ample experience in

walking and still were physically active in gait activities, to be considered experts in this sub-maximal and common motor task.

Actual gait ability was quantified based on $Width_{act}$, allowing 10% of erroneous steps. This choice of 90% was rather arbitrary and a more conservative value, for example 95%, shifts the distribution of the degree of misjudgment (Fig. 4b) to the right, leading to more participants underestimating their abilities than we currently observed. In comparison, in stepping over obstacles this parameter was set at 100% [19]. Several studies showed the shortcoming of some older adults to accurately perceive their actual ability [3,4,19], this notion is supported by our results.

Practical usability of the degree of misjudgment to pinpoint potentially harmful consequences in older adults, depends on how this measure translates to other daily life tasks. O'Brien and Ahmed [17] demonstrated that young adults consistently showed either risky or risk-averse movement behaviour in two different motor tasks. Likewise, it can be assumed that the degree of misjudgment generalises to other daily life activities.

Our objective was to quantify the misjudgment of walking ability in older adults. Such quantification allows direct comparison of the perceived and actual performance, thereby quantifying the degree of misjudgment on a continuous scale. Such a measure has been emphasised to be useful to include in fall risk assessments [4] and allow better personalised interventions. However, it is still unknown at which value the misjudgment becomes problematic.

5. Conclusion

Older adults' judgment of their gait ability in terms of accuracy can be evaluated by a path width paradigm. Accuracy seemed a

good estimate of physical capacities such as leg strength, and although no clear relation with a representative golden standard, $Width_{perc}$ is assumed to represent the perceived ability. Our proposed degree of misjudgment directly quantifies older individual's misjudgment between perceived and actual gait ability, irrespective of their performance level.

Acknowledgments

We thank Tim Dullaart and Myriam Sillevs Smitt for their help during the data collection, Bert Coolen for developing the projection software, and Richard Cassius for the development of the software for the treadmill's self-paced mode.

Conflict of interest statement

This research was funded by a VIDI grant (No. 91714344) from the Dutch Organisation for Scientific Research (NWO). No further conflicts of interest are declared by the authors.

References

- [1] K. Adolph, M. Eppler, Development of visually guided locomotion, *Ecol. Psychol.* 10 (January (2015)) (1998) 303–321.
- [2] M. Arvin, M. Mazaheri, M.J. Hoozemans, M. Pijnappels, B.J. Burger, S.M. Verschueren, J.H. van Dieën, Effects of narrow base gait on mediolateral balance control in young and older adults, *J. Biomech.* 49 (2016) 1264–1267.
- [3] A.A. Butler, S.R. Lord, J.L. Taylor, R.C. Fitzpatrick, Ability versus hazard: risk-taking and falls in older people, *J. Gerontol. A Biol. Sci. Med. Sci.* 70 (2015) 628–634.
- [4] K. Delbaere, J.C.T. Close, H. Brodaty, P. Sachdev, S.R. Lord, Determinants of disparities between perceived and physiological risk of falling among elderly people: cohort study, *BMJ* 341 (2010).
- [5] K. Delbaere, G. Crombez, G. Vanderstraeten, T. Willems, D. Cambier, Fear-related avoidance of activities, falls and physical frailty. A prospective community-based cohort study, *Age Ageing* 33 (July (4)) (2004) 368–373.
- [6] N. Deshpande, F. Zhang, Trunk, head, and step characteristics during normal and narrow-based walking under deteriorated sensory conditions, *J. Motor Behav.* 46 (December (2)) (2014) 125–132.
- [7] J. Desrosiers, G. Bravo, R. Hébert, É. Dutil, Normative data for grip strength of elderly men and women, *Am. J. Occup. Ther.* 49 (7) (1995) 637–644.
- [8] A.L. Hackney, M.E. Cinelli, Action strategies of older adults walking through apertures, *Gait Posture* 33 (4) (2011) 733–736.
- [9] A.L. Hackney, M.E. Cinelli, Older adults are guided by their dynamic perceptions during aperture crossing, *Gait Posture* 5 (2012).
- [10] J.L. Helbostad, R. Moe-Nilssen, The effect of gait speed on lateral balance control during walking in healthy elderly, *Gait Posture* 18 (October (2)) (2003) 27–36.
- [11] T. Hothorn, K. Hornik, M.A. van de Wiel, A. Zeileis, A lego system for conditional inference, *Am. Stat.* 60 (3) (2006) 257–263.
- [12] A. Hreljac, R.N. Marshall, Algorithms to determine event timing during normal walking using kinematic data, *J. Biomech.* 33 (6) (2000) 783–786.
- [13] G. Kempen, G. Zijlstra, J. van Haastregt, Het meten van angst om te vallen met de falls efficacy scale-international (FES-I), achtergrond en psychometrische kenmerken, *Tijdschr. Gerontol. Geriatrie* 38 (4) (2007) 178–184.
- [14] J. Konczak, H.J. Meeuwen, M.E. Cress, Changing affordances in stair climbing: the perception of maximum climbability in young and older adults, *J. Exp. Psychol.* 18 (3) (1992) 691–697.
- [15] J. Kruger, D. Dunning, Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments, *J. Personal. Soc. Psychol.* 77 (6) (1999) 1121–1134.
- [16] C. Lustig, P. Shah, R. Seidler, P. Reuter-Lorenz, Aging, training, and the brain: a review and future directions, *Neuropsychol. Rev.* 19 (4) (2009) 504–522.
- [17] M.K. O'Brien, A.A. Ahmed, Does risk-sensitivity transfer across movements? *J. Neurophysiol.* 109 (April (7)) (2013) 1866–1875.
- [18] P.M. Podsakoff, S.B. MacKenzie, J.-Y. Lee, N.P. Podsakoff, Common method biases in behavioral research: a critical review of the literature and recommended remedies, *J. Appl. Psychol.* 88 (5) (2003) 879–903.
- [19] R. Sakurai, Y. Fujiwara, M. Ishihara, T. Higuchi, H. Uchida, K. Imanaka, Age-related self-overestimation of step-over ability in healthy older adults and its relationship to fall risk, *BMC Geriatr.* 13 (2013) 44.
- [20] M.A. Schragger, V.E. Kelly, R. Price, L. Ferrucci, A. Shumway-Cook, The effects of age on medio-lateral stability during normal and narrow base walking, *Gait Posture* 28 (October (3)) (2008) 466–471.
- [21] O. Segev-Jacobovski, T. Herman, G. Yogeve-Seligmann, A. Mirelman, N. Giladi, J.M. Hausdorff, The interplay between gait, falls and cognition: can cognitive therapy reduce fall risk? *Expert Rev. Neurother.* 11 (7) (2011) 1057–1075.
- [22] S. Shin, R.J. Valentine, E.M. Evans, J.J. Sosnoff, Lower extremity muscle quality and gait variability in older adults, *Age Ageing* 41 (September (5)) (2012) 595–599.
- [23] L.H. Sloat, M.M. van der Krogt, J. Harlaar, Self-paced versus fixed speed treadmill walking, *Gait Posture* 39 (1) (2014) 478–484.
- [24] A.A. Vandervoort, Aging of the human neuromuscular system, *Muscle Nerve* 25 (January (1)) (2002) 17–25.
- [25] J.M. VanSwearingen, S.A. Studenski, Aging, motor skill, and the energy cost of walking: implications for the prevention and treatment of mobility decline in older persons, *J. Gerontol. A Biol. Sci. Med. Sci.* 69 (November (11)) (2014) 1429–1436.
- [26] A.M. Williams, K.A. Ericsson, Perceptual-cognitive expertise in sport: some considerations when applying the expert performance approach, *Hum. Mov. Sci.* 24 (June (3)) (2005) 283–307.
- [27] A.M. Williams, P.R. Ford, Expertise and expert performance in sport, *Int. Rev. Sport Exerc. Psychol.* 1 (March (1)) (2008) 4–18.
- [28] M. Woollacott, A. Shumway-Cook, Attention and the control of posture and gait: a review of an emerging area of research, *Gait Posture* 16 (August (1)) (2002) 1–14.
- [29] L. Yardley, N. Beyer, K. Hauer, G. Kempen, C. Piot-Ziegler, C. Todd, Development and initial validation of the falls efficacy scale-international (FES-I), *Age Ageing* 34 (6) (2005) 614–619.
- [30] V.M. Zatsiorsky, *Kinetics of Human Motion*, Human Kinetics, 2002.