CONTENTS

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ABSTRACT

Aim: The aim of this study was to investigate the effect of standing time and instruction on stance characteristic by describing and comparing quiet and prolonged standing.

Methods: Two conditions were tested – Quiet Standing (QS) for 1 min (4 trials) and Prolonged Standing (PS) for 30 min (1 trial). Data were collected with an AMTI force plate and a video camera. Centre of Pressure (CoP) and its SD, RMS, and area were calculated in Matlab and SPSS was used for statistical analysis.

Results: The QS trials did not significantly differ from each other on any of the variables, but the PS trial was significantly different from all QS trials. QS was characterized by a relatively stable position of CoP throughout the trial while PS was characterized by relatively stable periods interspersed with periods with larger CoP movements. In contrast to QS, CoP patterns such as shifts, drifts, and fidgets appeared in PS. Both multi-region and single-region standing appeared in PS, whereas QS was characterized by single-region standing. There were anthropometrical differences between the two groups. Further the multi-region group had significantly more sway during the QS than the single-region group.

Conclusion: The results from the present study indicate that standing time and instruction have an effect on stance characteristics. Variables traditionally used to study quiet standing were able to confirm that quiet and prolonged standing are significantly different, but failed to describe the respective characteristics in sufficient detail. Evaluation of sway patterns and anthropometrics revealed a possible connection between stance strategy in prolonged and quiet standing.

Key words: quiet standing, prolonged standing, postural sway, centre of pressure, centre of mass, shifts, drifts, fidgets, multi-region, single-region, anthropometrics.

INTRODUCTION

During any day, humans spend a considerable amount of time standing and it is easy to find examples of standing situations in the activities of daily living (ADL). We stand while waiting in a line or for the bus, while cooking, and some of us even have a standing job, such as a hair dresser. The literature literally flows over with studies that have investigated the standing position. Remarkably, few of these studies were actually interested in the act of standing. The more typical focus was the underlying ability to maintain balance (Collins & De Luca, 1993; Pai, 2003; Prieto, Myklebust, Hoffmann, Lovett, & Myklebust, 1996; Qu & Nussbaum, 2009; Winter, 1995). But how often do we actually stand as quietly and still as possible? It is mostly in highly specific situations like having a portrait or an x-ray taken, or when you are asked to stand still for another specific reason. Standing in ADL is usually less constrained and more relaxed, with the possibility to make postural changes, shift weight from one foot to the other, etc. In addition, standing in ADL often lasts longer than the 30-90 seconds used in many studies on quiet standing (Collins & De Luca, 1993; Doyle, Hsiao-Wecksler, Ragan, & Rosengren, 2007; Hue, Simoneau, Marcotte, Berrigan, Dore, Marceau et al, 2007; Prieto et al, 1996; Røgind, Lykkegaard, Bliddal, & Danneskiold-Samsøe, 2003). When it comes to unconstrained standing over longer periods of time, we still know remarkably little. This paradox was the starting point for this study. By describing and comparing the characteristics of quiet and prolonged standing, the hope was to get more knowledge about standing itself. The focus was specifically on the effects of standing time and instruction on stance characteristics.

Quiet standing has been the topic of numerous studies. The human upright position is inherently unstable, and the task of standing completely quiet therefore as good as impossible (Winter, 1995). In order to be able to stand, control of the movements of the centre of pressure (CoP) in relation to the centre of gravity (CoG) is necessary. It is crucial that the range of movements of CoG is smaller than the range of CoP movement. On the contrary, if the range of CoG movements exceed the movements of CoP, it is necessary to take a step to avoid falling. This process results in continuous corrections of the CoP and CoG relation, and the body is in constant movement (Winter, 1995). Postural sway has been the focus in many studies of quiet standing (Pai, 2003; Røgind et al, 2003; Visser, Carpenter, van der Kooij, & Bloem, 2008; Winter, 1995).

Several variables have been used to quantify postural sway, but the most common of these is to measure amount of CoP displacement (Prieto, Myklebust, & Myklebust, 1993; Winter, 1995). This measure has been viewed as an objective measure of postural capacity for both healthy subjects and patients (Rougier, 2008). The rationale behind these studies is the general believe that more sway during standing is linked to less stability (Pai, 2003). A usual procedure for balance evaluation is to ask the subjects to stand as quietly as possible, often over a short period of time and measure amount of sway. One limitation to studies of quiet standing is that there is still no consensus regarding the meaning of postural sway, and it is difficult to establish whether occurrence indicates good or bad balance skills (Visser et al, 2008). This point may be exemplified by the fact that there are examples where subjects with poor balance, for example different patient groups, have less sway than subject with no balance problems (Pai, 2003).

Over the last decade, a few published studies have investigated prolonged standing (PS) in both healthy adults (Duarte & Sternad, 2008; Duarte & Zatsiorsky, 1999, 2000, 2001), elderly (Freitas, Wieczorek, Marchetti, & Duarte, 2005), and people with chronic low back pain (Lafond, Champagne, Descarreaux, Dubois, Prado, & Duarte, 2009). These studies have asked the participants to stand on a force plate for 30 minutes without any instructions other than not to step off the plate, and the investigated task have therefore come closer to normal standing in ADL than the task in quiet standing. In contrast to the traditional way of looking at postural sway, Duarte et al. (1999) wanted to show that there are specific and persistent patterns in the movements of CoP during PS in healthy adults. The authors found three such patterns, namely shifting (a fast step-like change in CoP from one position to another), fidgeting (a fast and large displacement with a subsequent return of CoP), and drifting (a slow, continuous displacement of CoP). These three patterns were also found in the studies of Freitas et al. (2005) and Lafond et al. (2009) in older adults and people with low back pain. Another characteristic of PS is that it may appear as either multi-region or single-region standing if the movements of CoP in anterior-posterior (AP) and medio-lateral (ML) directions are plotted against each other. During multi-region standing, the subjects change the average position of CoP several times during the trial while during single-region standing, the average position of COP is concentrated in one area only (Duarte & Zatsiorsky, 1999).

Studies of PS have been used to differentiate between groups, for instance different age or patients groups from healthy subjects. Freitas et al. (2005) found differences in the COP characteristics between elderly and adults. Both the groups had all three COP-patterns, multi-region and single-region standing, but the postural changes of the elderly were of smaller amplitude and with less sway then the younger adults. Lafond et al. (2009) found that patients with chronic low back pain had fewer postural changes and less sway in prolonged standing than the control group. They also found that the patient group had more sway than the control group both before and after prolonged standing. Unlike the control group, the performance of the patients deteriorated as a result of the prolonged standing.

In sum, there are a few studies of prolonged unconstrained standing generally in the adult population and in some specific groups. However, these studies of PS have not compared their results with short quiet standing, and therefore it is still unknown how the two conditions relate to each other. Better knowledge of this topic may be important to those who stand over longer periods of time, for instance in their profession, and to those who have difficulties to stand over longer periods of time, for instance different patient groups or people with reduced balance. The aim of the present study was to take a closer look at standing especially the effect of standing time and instruction on stance characteristics. Both quiet and prolonged standing were investigated with respect to characteristics, similarities, and differences.

METHODS

Subjects

Twenty subjects, 10 men and 10 women, were recruited to the study from the local community and university. Among these, a subgroup of 11 subjects, 6 men and 5 women, came back and repeated the procedure in a second session. In session two, one of the subjects had to interrupt the prolonged standing trial after approximately 10 minutes. The data from this subject is excluded from the analysis of the second session. See Table 1 for descriptive statistics.

Table 1.
Subject characteristics

	Whole group			Subgroup		
Subjects	20			10		
	Mean	Range	SE	Mean	Range	SE
Age (year)	24.9	20-32	(0.75)	26.3	22-33	(1.00)
Height (cm)	178.7	161.7-197.3	(2.48)	178.1	161.3-197.7	(3.86)
Weight (kg)	75.5	61.5-95.6	(2.67)	76.0	62.1-94.2	(3.95)
BMI (††)	23.6	21.1-27.8	(0.47)	23.9	21.0-28.3	(0.69)
Waist Circ (cm)	79.3	69-92	(1.59)	79.5	71-91	(2.16)
Hip Circ (cm)	103.2	92-112	(1.13)	102.7	93-112	(1.86)
WH-ratio (†)	0.77	0.69-0.86	(0.01)	0.77	0.68-0.88	(0.19)

Abbreviations: Waist Circ = waist circumference, Hip Circ = hip circumference, WH-ratio = waist hip ratio, BMI = body mass index.
† BMI calculated as: weight (kg) / (height (m) x height (m))
†† Waist hip ratio is calculated as: waist circumference / hip circumference

The subjects had no known balance problems, were free of diseases and conditions known to influence balance, and they did not use any medication known to influence balance. Prior to the test, all subjects were given written and oral information about the experiment. They had the opportunity to ask questions before they signed a written consent.

Equipment

Forces and moments were registered with an AMTI force plate, 120 x 60 cm. In the first session, in which the whole group participated, the sampling rate was 50 Hz over 6 channels and a video camera (Sony VX) was placed behind the subject to record the movements. In the second session, with only the subgroup, the sampling rate was 50 Hz and the video camera was not used. In this session a short test (10 sec) with a known weight (50 kg) was preformed to register possible drift in the signal. The subjects' body mass was registered with a scale and a measuring band was used to measure waist and hip circumference. A regular cd player and an audio book were used during the prolonged standing.

Procedure

All testing took place in the movement laboratory at the Human Movement Science Programme at NTNU, Trondheim. Two standing conditions were tested; quiet standing (QS) and prolong standing (PS). In both conditions the subjects wore socks but not shoes. During

QS they were instructed to have their feet placed shoulder width apart, let the arms hang relaxed at their sides, have the eyes open and look straight ahead, and to stand as quietly as possible for 60 sec. They had four trials of QS, two before and two after PS. Between the short trials the subjects were allowed a short break. During PS the subjects were asked to stand relaxed and natural for 30 min. There were no instructions on how to stand, except not to step off the force plate. The subjects were asked to execute one trial of PS. To take the focus away from the task of standing, they listened to two fairytales followed by some easy questions. After the PS the subjects were given a short break in which they were allowed to sit down, stand or walk around before the two last trials of QS. The subgroup repeated the procedure in a second session approximately 2 months later using a higher sampling frequency and no video. The tester took notes of visible postural changes during the PS trials.

Data Collection and Analysis

Ground reaction forces and moments, both in 3D, were acquired from the force plate and used to calculate the centre of pressure (CoP) and the projection of the gravity line from centre of mass (pCoM). In the first step of analyzing the data, data from the whole group at a sampling frequency of 50Hz over 6 channels were used. Here the four QS trials were compared to each other and to the PS trial. The data from the subgroup were sampled at 50 Hz to enable a closer look at the PS trials, particularly calculation of pCoM. The video and the tester's notes were used as a back-up source to check whether large displacements of the CoP were related to visible body movements and/or postural changes.

Variables

Displacement of the CoP was quantified using three typical variables in quiet standing studies (Doyle et al, 2007; Lin, Seol, Nussbaum, & Madigan, 2008; Pinsault & Vuillerme, 2009; Prieto et al, 1996), namely standard deviation of CoP in both the AP and ML directions, RMS distance from mean CoP, and the CoP area (calculated by fitting an ellipse through the SD of CoP in AP and ML directions). Additional variables were visually analyzed in the PS trial from the subgroup data in session 2: shifts, drifts, and fidgets. Finally, centre of mass (CoM) was calculated and in order to display the projected line of gravity from CoM. Matlab version R2009a was used for all variable calculations. All statistical processing was done in SPSS version 16.0 and consisted of 2-way mixed model ANOVAs on Gender (2) X Condition (5) with repeated measures on Condition. Significant main effects on Condition were followed up by post-hoc comparisons with Bonferroni corrections. Independent-samples t-tests were executed to explore eventual differences between those who had a single region and those who had a multi-region standing pattern with regard to anthropometrics and in the summary measures of CoP in the four trials of QS standing (value of the four trials) and PS.

Ethics

The study was approved by the Regional Committee for Medical and Health Research Ethics (REK).

RESULTS

The Results section is divided into three parts. First, visible postural changes are described in short. The second part deals with CoP characteristics in terms of raw CoP displacement, description of stabilograms (CoP AP displacements plotted against CoP ML displacements), and statistical analyses. In the analysis, the summary measures of CoP (SD, RMS, and area) are investigated and data from the entire group at session 1 is used. In the last part, qualitative patterns in CoP displacement are described with respect to shifts, drifts, fidgets, and the relation between CoP and the projected line of gravity from CoM (pCoM). For this latter part, data with a higher sampling frequency from the subgroup at session 2 is used.

Visible Postural Changes

A review of the video and the tester's notes from the test sessions revealed that none of the subjects made large, visible body movements or postural changes during QS and that all participants in both sessions made postural changes during the prolonged standing trial. However, there were large individual differences with respect to the frequency and type of postural change during the PS trials. Examples of postural changes seen in this study were movements of the upper body, weight shift from one foot to the other, small steps, and adjustments in feet placement.

Analysis of CoP Displacement

To get a first impression of possible differences between quiet and prolonged standing, the displacements in CoP position were plotted over time in medio-lateral and anterior-posterior directions separately. As can be seen in a typical example in Figure 1, quiet standing were characterized by only small fluctuations in CoP and the frequency and amplitude of displacements were smaller than during prolonged standing. The PS trials, on the other hand, had periods of relative stability interspersed with sudden, larger movements. The interval and duration of the movements varied both within a trial and across subjects. Furthermore, the large movements could happen anywhere in the 30 minutes trial, with no clear trend of change across the trial. A manual check of the video from the taped sessions confirmed that postural adjustments took place at the same time as large displacements of the CoP in medio-lateral direction. Since the camera was placed directly behind the participants, movements in anterior-posterior direction were harder to detect from the video.

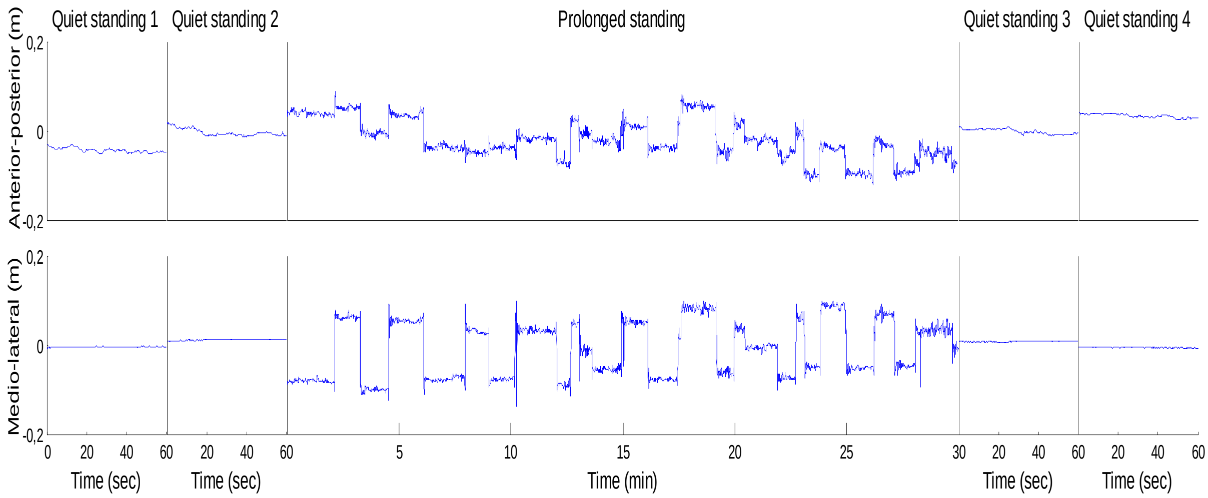

Figure 1: Raw CoP movements in anterior-posterior (top panel) and medio-lateral (bottom panel) directions in one typical subject for four QS trials and one PS trial.

Measures typically used in QS studies were used to summarize CoP displacement: standard deviation (SD) of mean CoP for AP and ML directions separately, RMS distance from mean CoP, and area of CoP displacement. These measures enabled comparison of quiet standing with prolonged standing within and across subjects.

Mean values of the variables for quiet and prolonged standing are shown in Figure 3. As can be seen in the figure, the mean value for the PS trial was markedly higher than for any of the

QS trials for all variables. Two-way ANOVAs with Condition (5) X Gender (2) confirmed significant differences between the conditions for all variables (SDap: $F(4,15) = 8.22$, $p = .001$; SDml: $F(4,15) = 13.93$, $p < .0005$; RMS: $F(4,15) = 13.66$, $p < .0005$; Area: $F(4,15) = 6.63$, $p = .003$). Post-hoc comparisons with Bonferroni corrections indicated that there were no significant differences between the four quiet standing trials for any of the variables (all p's ≥.13), whereas prolonged standing differed significantly from every quiet standing trial for every variable (all p's ≤ .001). There were no significant main or interaction effects for Gender (all p's > .16).

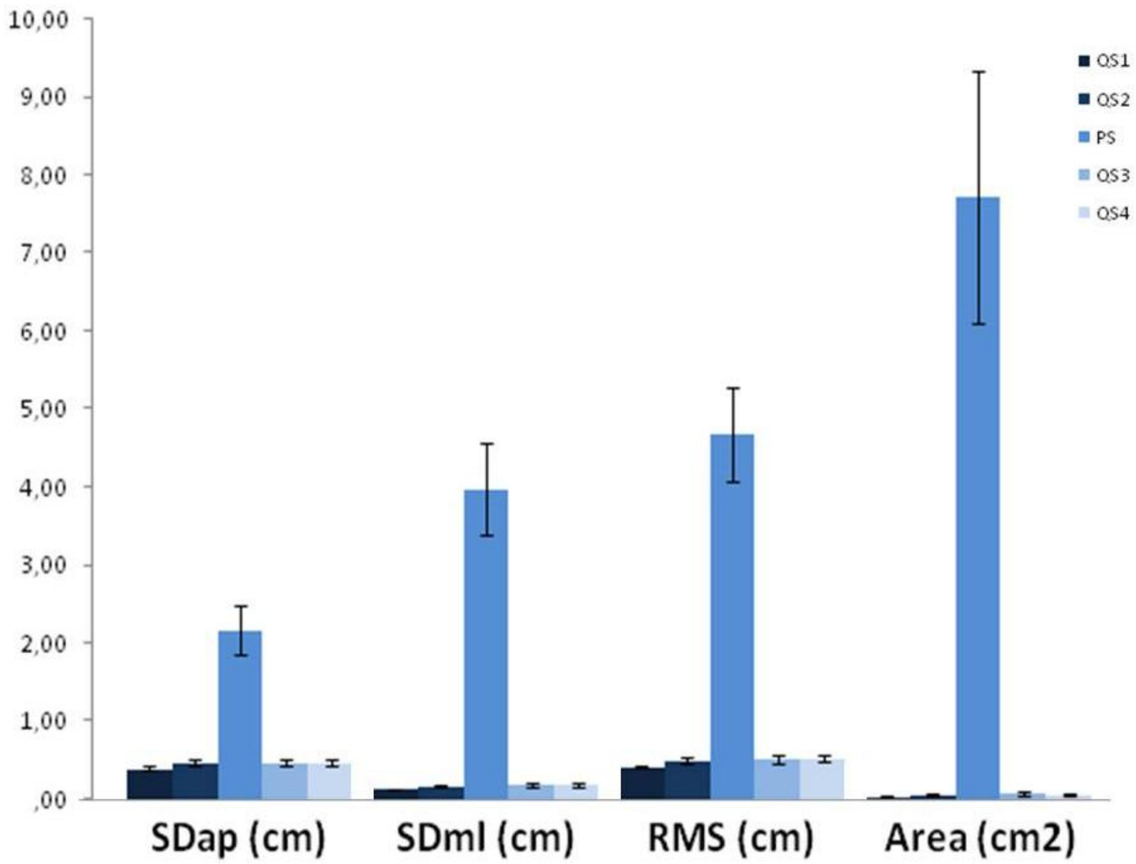

Figure 2: Mean values and standard error for the four variables standard deviation in anterior-posterior (SDap) and medio-lateral (SDml) directions, RMS, and area in quiet standing (QS1-4) and prolonged standing (PS).

Inspection of the stabilograms emphasized the difference between quiet and prolonged standing. The area of CoP displacement was markedly larger for the PS trials than for the QS trials (see Figure 3). Additionally, all QS trials were single-region trials, while the PS trials appeared as either multi- or single-region trials. In the multi-region trials the subject did not move the CoP within one single area, but moved it within and between several smaller, preferred areas. These areas appear as darker spots in the stabilograms. One example of quiet standing and 2 examples of prolonged standing (one single-region and one multi-region) are illustrated in Figure 3.

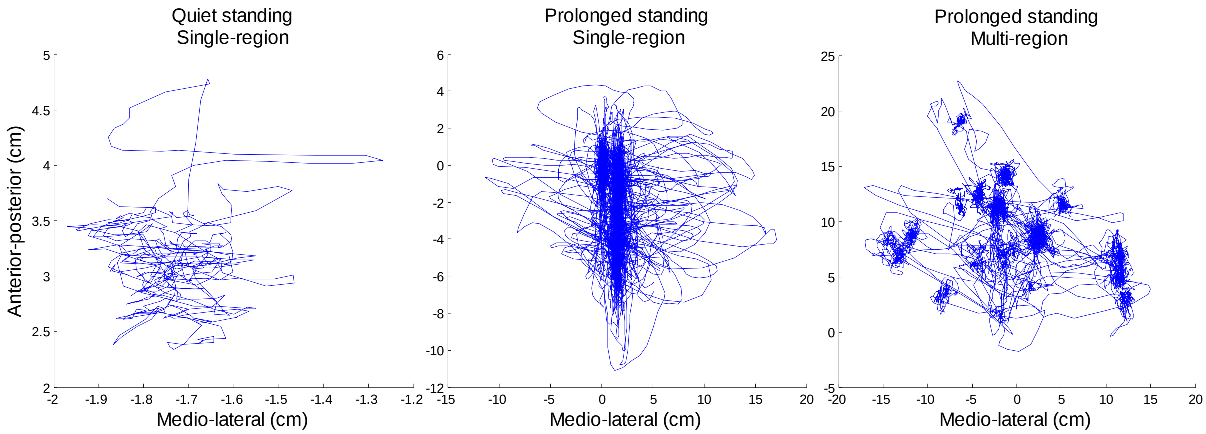

Figure 3: Displacement of CoP in AP against ML directions for one trial of quiet standing and two trials of prolonged standing (example of single-region and multi-region standing). Note the different scales in the three figures.

The division between multi-region and single-region trials during PS was further explored. Most subjects, 15 out of 20, had a multi-region pattern during PS. The remaining 5 subjects had a single-region pattern. Possible differences between the subjects with multi-region and the subjects with single-region patterns during PS were investigated with independent-samples t-tests between two groups, single- and multi-region, on anthropometric data and the summary measures of CoP (SDap, SDml, RMS, and area) for both QS and PS trials. With regard to the QS trials, the mean of the four trials was used as dependent measure. Table 2 displays the results of the t-tests between the groups on anthropometric data, mean values of the four QS trials, and the values from PS. With respect to the anthropometric measures, there were significant differences between the groups on weight, BMI, waist circumference, and hip circumference. Additionally there was a non significant difference in height between the two groups. Not surprisingly, the values of all four variables in prolonged standing were significantly larger for the multi-region group than for the single region standing group. Interestingly though, 2 of the variables, SDap and RMS, were also significantly larger for the multi-region group compared to the single-region group in the QS trials.

Table 2.
Characteristics and differences between the single-region and multi-region standing groups for the variables age, height, weight, waist and hip circumference, waist/hip ratio, body mass index, standard deviation in anterior-posterior (SDap) and medio-lateral (SDml) directions, RMS, and area in quiet standing (QS) and prolonged standing (PS). Significant differences are marked with * ($p < 0.05$).

	Single-region		**Multi-region**		**t**	**p**
Subjects	5		15			
	Mean	SE	Mean	SE		
Age (year)	23.4	(1.36)	25.3	(0.88)	-1.2	.269
Height (cm)	173.6	(1.68)	180.4	(3.18)	-1.9	.074
Weight (kg)	65.7	(2.54)	78.8	(3.03)	-3.3	.005*
BMI (†)	21.8	(0.42)	24.2	(0.53)	-3.4	.003*
Waist Circ (cm)	74.2	(2.03)	81.0	(1.83)	-2.5	.030*
Hip Circ (cm)	99.0	(1.45)	104.5	(1.25)	-2.9	.015*
WH-ratio(cm) (††)	0.75	(0.02)	0.77	(0.01)	-0.8	.458
Quiet standing						
SDap	0.35	(0.03)	0.49	(0.03)	-3.8	.002*
Sdml	0.14	(0.02)	0.17	(0.02)	-1.2	.258
RMS	0.38	(0.03)	0.52	(0.03)	-3.3	.005*
Area	0.04	(0.01)	0.06	(0.05)	-2.0	.061
Prolonged standing						
SDap	1.05	(0.27)	2.58	(0.35)	-3.5	.003*
Sdml	1.30	(0.38)	5.19	(0.52)	-6.0	.000*
RMS	1.72	(0.43)	5.98	(0.50)	-6.5	.000*
Area	1.22	(0.50)	10.18	(1.73)	-5.0	.000*

Abbreviations: Waist Circ = waist circumference, Hip Circ = hip circumference, WH-ratio = waist hip ratio, BMI = body mass index.
† BMI calculated as: weight (kg) / (height (m) x height (m))
†† Waist hip ratio is calculated as: waist circumference / hip circumference

Both the plots of raw CoP displacement and the summary measures showed that the prolonged standing trials had a baseline approximately at the level of, or slightly higher than, the mean scores from the QS trials, interspersed with spikes of higher scores. As previously described, the statistical measures (mean and standard error) gave statistically significant higher values for the PS trials than the QS trials for all variables. The characteristic of a multi-regional pattern, however, is lost by applying these measures to prolonged standing, and the analysis will therefore give a misleading picture of the characteristics of PS. These characteristics will be described in more qualitative detail below.

Qualitative Patterns in CoP Displacements

In order to describe the CoP patterns during prolonged standing, the displacements of CoP were plotted over time for anterior-posterior and medio-lateral directions separately. These plots were visually inspected with respect to the occurrence of shifts, drifts, and fidgets in both short and prolonged time series. Furthermore, CoP displacements were studied with respected to the projected line of gravity from the CoM (pCoM).

Quiet Standing

Even during short, quiet standing, the CoP does not remain stationary but displays small fluctuations. However, none of the three patterns shifts, drifts, or fidgets was visibly detectable in the quiet standing trials in any of the subjects (see Figure 4).

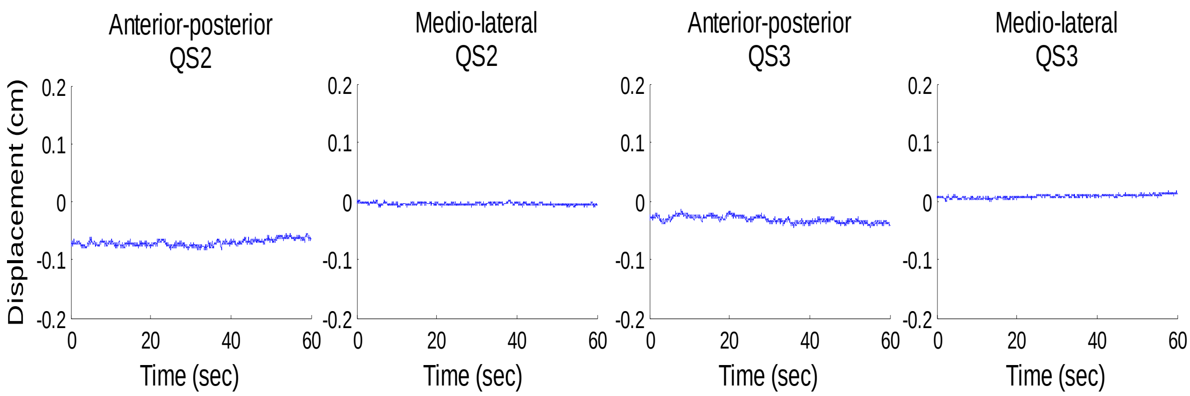

Figure 4: Examples of quiet standing before (QS2) and after prolonged standing (QS3). All examples are from one typical subject in anterior-posterior and medio-lateral direction.

Prolonged Standing

As shown in Figure 5, the CoP showed both smaller and larger fluctuations during prolonged standing. As for the first data collection, the subject's stabilograms showed both multi-region and single-region standing. In addition, all three patterns shifts, drifts, and fidgets visibly appeared in the prolonged standing trials. However, there were differences both between AP and ML directions and across subjects regarding the displayed patterns, and the frequency and amplitude of these patterns. For most subjects, shifts were the predominating pattern in ML direction (see subject A in Figure 5), while drift and fidgets were most marked in AP direction. Nine out of 10 subjects had larger amplitude of CoP displacement in ML direction than in AP direction. For the last subject (subject C in Figure 5), the amplitude was more similar in both directions. Each of these patterns will be described in more detail below.

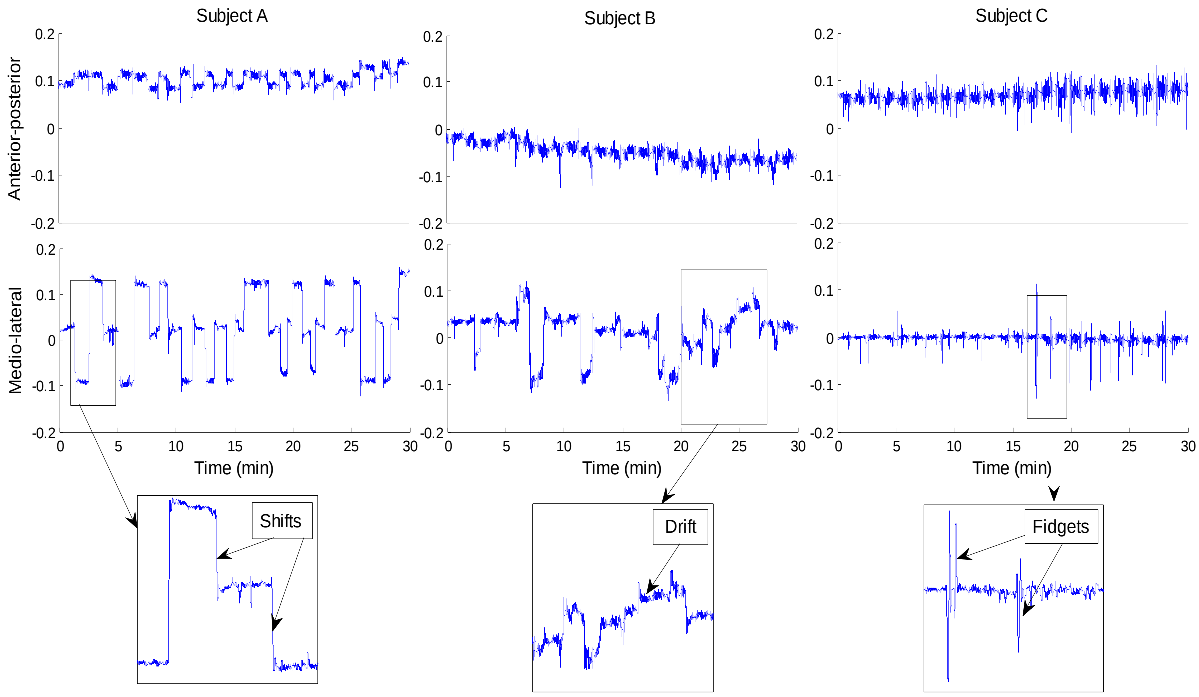

Figure 5: Displacement of CoP in anterior-posterior (top panels) and medio-lateral (middle panels) directions for three subjects during the 30 minutes prolonged standing trial. In the bottom panels, enlarged examples of the three CoP patterns "shifts", "drifts" and "fidgets" are illustrated.

Shifts

Nine out of 10 subjects had visible shifts in ML, AP, or both directions during prolonged standing. For most subjects, 7 out of 10, the movements of CoP in ML direction were dominated by shifts (see for example subject A). However, the amplitude and number, and thus the interval between the shifts, varied between the subjects. Two of the subjects had only 1 shift while another subject had almost 50 shifts. Within each trial, the shift frequency seemed quite regular across the entire time series. In AP direction, 5 of the subjects had visible shifts while 5 did not have visible shifts. For most subjects the appearance of shifts was less frequent in AP than in ML direction and only one of the subjects had a pattern that was dominated by shifts in AP direction. In medio-lateral direction, the shifts seemed to be more regular with respect to amplitude within a trial, than the shifts in anterior-posterior direction. This was particularly evident in 7 of the subjects in which the CoP displacement had three relatively stable levels interspersed with shifts (subject A in Figure 5 exemplifies this).

Drifts

Occurrences of drift in the CoP time series were less obvious and more subjective than shifts and fidgets. Visual inspection of the movements of CoP implied that 8 out of 10 subjects had periods with drifts in CoP position during prolonged standing in both AP and ML direction. The amplitude and frequency of drifts differed both within trials and across subjects. Some of the subjects had several shorter drifts while others had a few long drifts over almost the entire time series.

Fidgets

All subjects had at least one fidget in both directions during prolonged standing. As for the shifts and drifts, the number of fidgets during PS differed across subjects. Some subjects had many fidgets in both directions, while most subjects had more fidgets in AP than in ML directions. For three of the subjects that had only a few or no shifts in ML direction, the movements of CoP tended to be better characterized by fidgets. These subjects had more fidgets, up to 30 in ML direction, than the subjects with more shifts, who had down to 1 or 2 fidgets in ML direction.

The relationship between CoP and CoM

The most common way to study postural sway is to investigate the movements of CoP. However, the movements of CoM are a more direct reflection of body movements. Therefore, the movements of CoP in relation to CoM are relevant as an additional measure of postural sway. In order to get more information about the relationship between the movements of CoP and CoM during PS, the displacements of CoP and of the projected line of gravity from CoM to the ground (pCoM) were plotted together. As can be seen in the top panels of panel B and C in Figure 6, movements of the two lines follow each other closely. The movements of pCoM have a slightly lower frequency, with the higher frequency movements of CoP fluctuating around pCoM. The illustration of the residual CoP (the movements of pCoM subtracted from CoP) emphasize this relationship. The spikes in the residual CoP indicate where the movements of CoP deviate more from the movements of pCoM. Furthermore, the larger spikes in the trace of the residual CoP seem to coincide with the shifts and fidgets seen in the displacement of CoP.

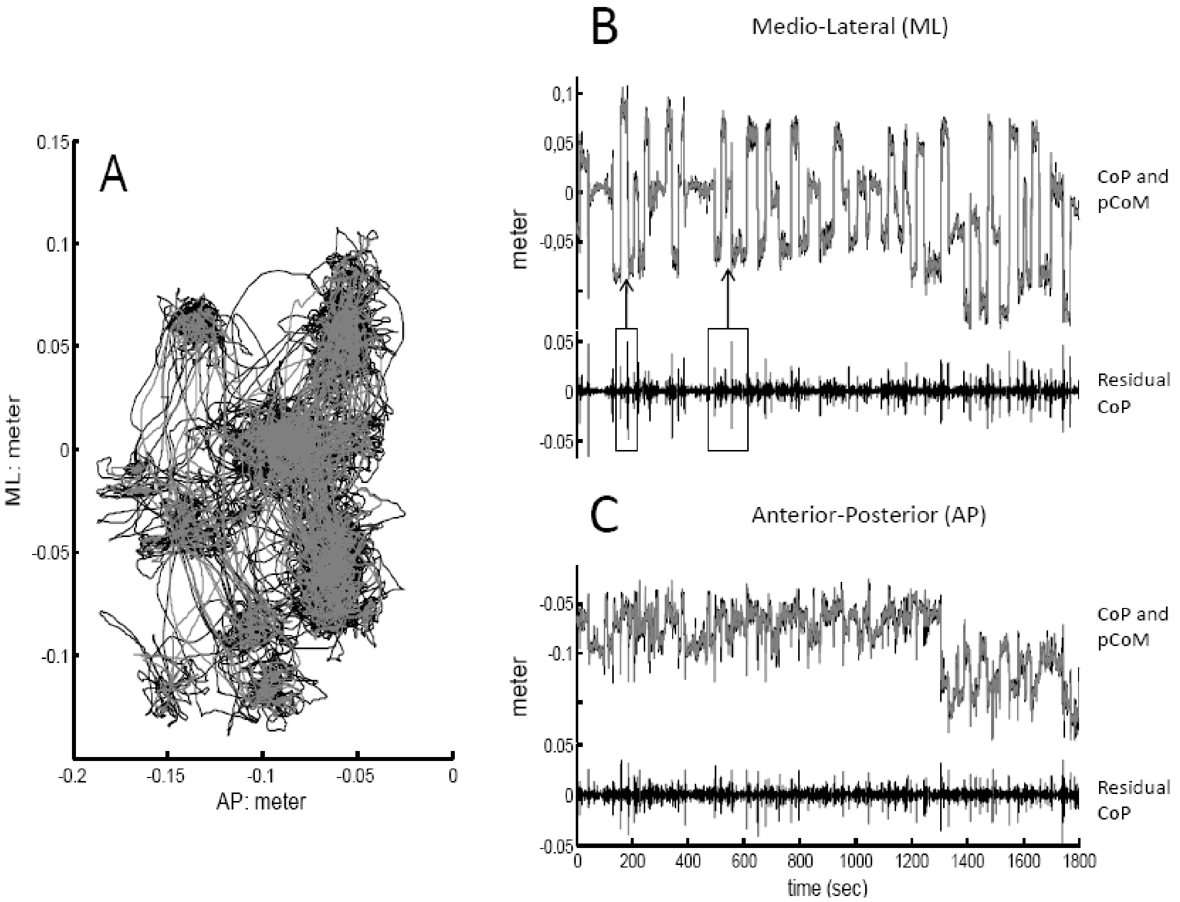

Figure 6: (A) A representative example of the stabilogram of CoP (*black trace*) and pCoM (*gray trace*) during 30 minutes of prolonged standing. (B-C) The same CoP and pCoM traces displayed in time for the ML (*upper panel in B*) and AP (*lower panel in C*) directions. The residual CoP – pCoM traces are displayed below the CoP and pCoM trace in each panel. The two boxes (B) indicate periods with a large difference between CoP and pCoM, and the arrows points to the concurrence with shifts. (Figure reprinted with minor adaptations from Ihlen, Lund, & Vereijken (2010).)

DISCUSSION

The aim of this study was to evaluate the effect of time and instruction on stance characteristics, focusing on differences and similarities between short quiet and prolonged relaxed standing. The results showed that quiet and prolonged standing have very different characteristics and were significantly different with respect to measures typically used in research on quiet standing, namely SD, RMS, and area of sway. Additionally, features of sway were identified in qualitative descriptions of patterns that were not captured by the traditional measures of sway typically used in studies on quiet standing. The qualitative descriptions revealed that some subjects swayed within a single region, whereas the majority swayed in multiple regions. These two groups also differed in anthropometric characteristics, with subjects in the multi-region group on average being heavier and having higher BMI, and waist and hip circumference. Surprisingly, the multi-region group also had significantly more sway during the short quiet standing trials than the single-region group.

Effect of Time and Instruction on Stance characteristics

The present study has evaluated the effect of time and instruction on stance characteristics, and these effects will be discussed terms of amount and patterns of postural sway. As time and instruction were not manipulated independently, it is not possible to conclude whether the differences between quiet and prolonged standing are an effect of one or both factors and they will therefore be discussed together.

Amount of postural sway

Based on the results of this study, it is clear that changing standing time and instruction of how to stand have large effects on stance characteristics. These differences were seen as highly enlarged values in all sway measures during prolonged standing compared to quiet standing. The small values in quiet standing pointed out that subjects, when asked to stand as quietly as possible actually do manage to stand rather quietly. In the prolonged standing trial the possibility to decide how to stand and whether or not to adjust the position, gave rise to more movement. However, the qualitative descriptions showed that prolonged standing is not only characterized by more movement but rather by periods with less sway and periods with more sway, implying that subjects stand both relatively quiet and with more postural sway. This characteristic was not picked up at all by the usual measures of sway. The generally inflated values in prolonged compared to quiet standing confirmed that the two conditions were very different from each other, but failed to give a description of the different patterns that are visible in postural sway when standing relaxed over longer periods of time.

Remarkable, the result indicated there were no differences between the four trials of quiet standing with respect to the variables used in this study. This indicates that normal healthy people, when repeatedly asked to stand as still as possible, manage to reproduce the task with high reliability. In addition to allowing investigation of test-retest reliability, comparing the four trials of quiet standing also gave information about possible effects of prolonged standing on subsequent quiet standing. Since there were no significant differences between the four trials of quiet standing, the prolonged standing appeared to have had little or no effect on the last two trials of quiet standing. There is some discrepancy in the literature regarding the effect of prolonged standing on a subsequent quiet standing trial. Both Freitas et al. (2005) and Lafond et al. (2009) compared amount of postural sway during quiet standing before and after prolonged standing. Because they only used some of the same measures of postural sway, a direct comparison between their results, and with the present study, is problematic. Nevertheless, both these studies found indications of increased postural sway for one or more of the used variables. As a contrast to the results in this study, Lafond et al. (2009) found an increase in sway area in quiet standing after prolonged standing in healthy adults. Different methods used to calculate sway area might partly explain the different results. Both methods calculate two axes and fit an ellipse around these. The difference is the method used to find the axes. Principal component analysis, as used by Lafond et al. (2009), finds axes related to the actual sway direction (Oliveira, Simpson, & Nadal, 1996) while the method in this study used the anterior-posterior and medio-lateral directions as axes. It is possible that the method used in the present study was less sensitive to small changes and that it overestimated the sway area more than the principal component analysis. Nevertheless, any method of fitting an ellipse around two axes will overestimate the sway area because subjects' sway trajectories do not cover the entire ellipse.

The effect of a prior activity on quiet standing has been studied earlier (Lepers, Bigard, Diard, Gouteyron, & Guezennec, 1997; Nardone, Tarantola, Giordano, & Schieppati, 1997). Lepers et al. (1997) used several variants of quiet standing, including one similar to the variant used in the present study. In accordance with the present study, they did not find any effect of the prior activity on that variant of quiet standing. However, the exercise had an effect on some of the more challenging variants of quiet standing. Further, it has been suggested that the intensity of a prior activity influences whether or not stability in subsequent quiet standing is affected. For instance, the study of Nardone et al. (1997) investigated the effect of exercise over and under the anaerobic threshold, and found that only exercise over this threshold increased postural sway in subsequent quiet standing. With this in mind, the prolonged standing activity used in the present study, should not be expected to reduce stability in a subsequent quiet standing trial in healthy adults, and the results from the present study support this line of argumentation.

Patterns of Postural Sway

Another difference between quiet and prolonged standing is the division into groups that showed single-region versus multi-region standing during prolonged standing, a division that was not found in quiet standing. This division is consistent with earlier studies of prolonged standing (Duarte & Sternad, 2008; Duarte & Zatsiorsky, 1999, 2001; Freitas et al, 2005). However, the relationship between single- and multi-region standing trials in healthy adults differs across studies, and earlier results both support and contradict the findings of the present study. Some studies have reported a majority of single-region trials (Duarte & Sternad, 2008; Duarte & Zatsiorsky, 1999), whereas other have found a majority of multi-region (Freitas et al, 2005) trials. Freitas et al. (2005) suggested that different counting criteria and experimental conditions might have contributed to this difference. The study of Freitas et al. (2005) compared prolonged standing in elderly to younger adults, and found that elderly tended to have a single-region pattern, while younger adults more typically displayed a multi-region pattern. Difficulties in shifting weight from one foot to the other and fear of falling in the elderly were suggested as possible explanations for this difference.

Earlier studies of prolonged standing have described three patterns in the CoP movements, namely shifts, drifts, and fidgets (Duarte, Harvey, & Zatsiorsky, 2000; Duarte & Zatsiorsky, 1999; Freitas et al, 2005; Lafond et al, 2009). These patterns were visually identified in this study as well. The finding that these patterns appeared only during prolonged standing, underlines the difference in stance characteristics between quiet and prolonged standing. These patterns are all thought to be a result of body movements, among these, shifts and drifts are the result of a more permanent change of position than fidgets (Duarte & Zatsiorsky, 1999). The purposes of the different patterns are still not clear, but it is suggested that fidgets may serve to release foot discomfort, prevent swelling (Duarte & Zatsiorsky, 1999), or facilitate blood circulation (Duarte et al, 2000) and that shifts and drifts contributes to postural control (Duarte & Zatsiorsky, 1999).

In accordance with previous studies (Duarte et al, 2000), the results from the present study found differences across subject regarding which pattern was most dominate during prolonged standing. This between-subject difference has been interpreted as different strategies for postural change (Duarte et al, 2000). The present knowledge about these patterns is not sufficient to explain the differences in personal preferences of pattern. Possible explanations may be that these preferences mirrors that different strategies may obtain the same goal or it could be a result of differences in anthropometrics or balance control.

Another issue worth considering is the possible influence of personal factors. After the trial of prolonged standing, the subjects were asked how it felt to stand for 30 minutes. The answers were quite various. One of the subjects reported that it felt highly unnatural, regardless of the possibility to adjust the position, while others said it was quite common for them to stand over a longer period of time, for instance during work. Additionally, in the present study the subjects listened to fairytales during the prolonged standing and the reactions of this varied. Some said it took the attention away from the act of standing, while others found it boring. Although it may be difficult to control for these factors in a study, one should be aware of their possible contribution to differences across the subjects.

The present qualitative investigation of patterns during prolonged standing did not find any clear changes throughout a prolonged trial neither in form of a steady increase nor a steady decrease in the number or amplitude of postural changes. This implies that the characteristics of prolonged standing do not gradually appear later in the trial as the subject is getting fatigued, but are present from the beginning of the trial. Further, this suggests that the instruction to stand relaxed might have more effect on standing characteristics than the length of standing. Furthermore, these results imply that it might be possible to study groups that have difficulties with standing over a shorter period of time without losing the characteristic sway patterns of prolonged standing. To stand for exactly 30 minutes may not necessarily be what is most important, it might be more crucial that the subjects are allowed to stand as naturally as possible. On the other hand, the results from this study are only partly supported by results from earlier studies. Although Lafond et al. (2009) reported no change in numbers of patterns from the first to the last 15 minutes of prolonged standing for healthy adults or persons with chronic low back pain, Freitas et al. (2005) reported a change in amplitude in some of the patterns for both healthy adults and elderly. The discrepancy between the results of the present and the two earlier studies, may in part be a consequence of different quantification methods (computerized analysis versus visual inspection), and different duration of the time periods studied (first versus last 10 or 15 minutes). Taken together, the inconsistency in results underscores the need for further studies. One focus of attention could be to establish whether or not different patient groups have similar results regarding number and amplitude of postural changes throughout prolonged standing as healthy adults. It has been suggested that the quality of a subsequent trial of quiet standing is influenced by the intensity of that prior activity (Nardone et al, 1997). Different subject groups may experience the intensity of prolonged standing differently. For instance, the activity of relaxed standing over 30 minutes might not be quite as exhausting for healthy adults as for persons with a balance disorder. An interesting topic for further research could be to investigate whether the absolute standing time, or the relative time to exhaustion, is related to changes in the frequency of postural changes.

In this study, postural sway was visually inspected for the patterns of shifts, drifts, and fidgets. Previous studies (Duarte et al, 2000; Duarte & Zatsiorsky, 1999; Freitas et al, 2005; Lafond et al, 2009) that described and analysed prolonged standing by these patterns, used a computerized analysis to detect the patterns. At first sight, the standardized detection and quantification in these other studies may appear as an undisputable strength compared to the qualitative and subjective analyses of the present study. However, computerized analyses of these patterns crucially depend on several subjective choices that have to be made by the researchers. For example, it is necessary to set a cut-off value regarding the amount of CoP displacement and a window size in which to look for the patterns. In the computerized analysis, the cut-off threshold for the patterns was based on standard deviation of CoP displacement within a certain period of time, while the duration of the patterns was set by a maximum and absolute period of time (Duarte & Zatsiorsky, 1999). The specific choices for all three values affect the number of patterns found within a trial and according to Duarte and Zatsiorsky (1999) the most important parameter is the threshold for the patterns. Even though the authors tested the effect of these parameters and chose cut-off values based on these tests, there is nevertheless residual subjectivity affecting the results. Furthermore, the pattern recognition algorithm in these studies was based on standard deviation within a window and not an absolute value of displacement. The result of this may be that a movement from a person who generally moves little will be recognized as for instance a shift, while the same movement (in terms of absolute values) from a person with generally much movements not necessarily will be counted as any pattern at all. This subjectivity, despite the computerized analysis, in combination with the goal of this study, to describe and compare and not just to quantify the characteristics of quiet and prolonged standing, contributed to the decision that a qualitatively description was sufficient at this stage.

Effect of body characteristics on postural sway

The present study found interesting differences in anthropometric characteristics between the group with single-region and the group with multi-region sway pattern during prolonged standing. The latter were on average heavier, with higher BMI, and waist and hip circumferences. These results suggest that differences in body characteristics contribute to different standing strategies during prolonged standing.

The relationship between anthropometrics and stance characteristic has been studied before. Earlier studies on quiet standing have suggested that body characteristics as weight (Blaszczyk, Cieslinska-Swider, Plewa, Zahorska-Markiewicz, & Markiewicz, 2009; Hue et al, 2007; Røgind et al, 2003; Singh, Park, Levy, & Jung, 2009) and to some extent also height (Hue et al, 2007), have an influence on postural stability. The study of Singh et al (2009) suggests that weight have an influence on postural sway in prolonged quiet standing. In this study, increasing weight was found to increase postural sway. However, none of the previous studies on prolonged unconstrained standing have focused on anthropometric differences and possible effect between subjects with single-region and multi-region standing patterns. Interestingly though, Freitas et al (2005) reported that the adult group tended to stand in multi regions and was taller than the elderly group who tended to stand in single regions, but the difference in height was not significant. The same trend was seen in the present study. Freitas et al (2005) did not report other anthropometric differences or explore possible connections between anthropometrics and single- and multi-region standing. It is therefore not possible to say if the grouping into elderly as single-region standers and adults as multi-region standers was affected by anthropometric differences. Surprisingly, the difference in strategy between these two groups was also reflected in quiet standing, indicating that the groups have different amounts of sway during quiet standing as well. In light of this, the result in the study of Røgind et al. (2003) is interesting. They found that body weight not only influenced amount of postural sway, but also the choice of balance strategy in quiet standing. This influence was seen as a decreased use of ankle-strategy and increased use of hip-strategy with increasing weight. In other words, heavier persons used movements around the hip rather than movements around the ankles in order to maintain balance.

In other words, there are indications of a relationship between anthropometrics and stance characteristics in quiet standing, regardless of stance duration, and in both quiet and unconstrained prolonged standing. Taken together the results from the present and earlier studies indicates that anthropometrics may have an influence not only on amount of postural control during standing, but also that it contributes to different strategies in both forms of standing.

Centre of Pressure versus Centre of Mass

Postural sway can be studied and quantified in several ways. The present study used movements of centre of pressure, the projected line of gravity from centre of mass, and an additional combined measure of the two looking at the centre of pressure movements around the centre of mass movements. The relationship between centre of mass and centre of pressure is important for balance control in both standing and gait. While standing, the centre of mass needs to be within the range of the base of support. During gait on the other hand, the goal is to move the centre of mass outside the base of support so as to make a step, without falling (Winter, 1995). All the subjects made postural changes during prolonged standing, mainly in form of movements of the upper body, weight shifts from one foot to the other, small adjustment in foot placement, or small steps. These movements were related to episodes of shifts in the centre of pressure trajectory. In other words, the subjects remained standing, but altered the position from time to time. One might view these periods of shifts during prolonged standing as a combination of standing and walking, and the episodes of shifts as similar to the initiation and termination phases. In resemblance to shifts, the relative movements of centre of pressure exceed the movements of centre of mass during these phases of gait (Winter, 1995). Through a trial of prolonged standing, the centre of pressure fluctuates around the trajectory of centre of mass during prolonged standing. Periods of position changes, like shifts, resulted in increased deviation between the movement of centre of pressure and the movement of centre of mass in prolonged standing. Based on the results from the present study it appears as though a similar process occurs during shifts. In other words, during movements like shifting of weight from one foot to the other, the movements of centre of pressure are larger than the movements of centre of mass. Further exploration of the relationship between centre of pressure and centre of mass would be useful in order to shed more light on postural control during prolonged standing.

Conclusion

The present study has shed further light over a relatively new area of research, namely prolonged standing. There are still many unanswered questions regarding the characteristics of prolonged standing and how it is related to quiet standing. The results from the present study indicate that standing time and instruction have an effect on stance characteristics. Variables traditionally used to study quiet standing were able to confirm that quiet and prolonged standing are significantly different, but failed to describe the respective characteristics in sufficient detail. Interestingly, the evaluation of sway patterns during prolonged standing revealed a possible connection between stance strategy in prolonged and quiet standing. The results implied that persons that tend to stand in multi region during prolonged standing, have more postural sway in quiet standing, and that these strategies were influenced by anthropometric characteristics.

In sum, the remaining questions and inconsistencies in results between different studies underscore the need for further studies. One of the next steps might be to quantify the different postural patterns. This might give additional and more comparable information about prolonged standing. For instance, a quantification of postural patterns might give the opportunity to further explore the anthropometric differences between single- and multi-region standers during prolonged standing. It would also be fascinating to explore possible differences between the two groups with regard to the relative movement of centre of mass and centre of pressure. It would be of interest to get information whether these groups differ in the actual displacements of centre of mass or if the difference rather is in the fluctuations of centre of pressure around centre of mass. Furthermore, the results of the present study motivate the study of relaxed standing in groups that are known to have increased challenges regarding balance control, such as frail elderly and persons with cerebral palsy. These studies might indicate differences in strategies that might inform about underlying changes in control and offer ideas for intervention.

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