Coenen, P. and Parry, S. and Willenberg, L. and Shi, J. and Romero, L. and Blackwood, D. and Healy, G. et al. 2017. Associations of prolonged standing with musculoskeletal symptoms—A systematic review of laboratory studies. Gait and Posture. 58: pp. 310-318.

Abstract

While prolonged standing has shown to be detrimentally associated with musculoskeletal symptoms, exposure limits and underlying mechanisms are not well understood. We systematically reviewed evidence from laboratory studies on musculoskeletal symptom development during prolonged (≥20 minutes) uninterrupted standing, quantified acute dose-response associations and described underlying mechanisms.

Peer-reviewed articles were systematically searched for. Data from included articles were tabulated, and dose-response associations were statistically pooled. A linear interpolation of pooled dose-response associations was performed to estimate the duration of prolonged standing associated with musculoskeletal symptoms with a clinically relevant intensity of ≥9 (out of 100).

We included 26 articles (from 25 studies with 591 participants), of which the majority examined associations of prolonged standing with low back and lower extremity symptoms. Evidence on other (e.g., upper limb) symptoms was limited and inconsistent. Pooled dose-response associations showed that clinically relevant levels of low back symptoms were reached after 71 minutes of prolonged standing, with this shortened to 42 minutes in those considered pain developers. Regarding standing-related low back symptoms, consistent evidence was found for postural mechanisms (i.e., trunk flexion and lumbar curvature), but not for mechanisms of muscle fatigue and/or variation in movement. Blood pooling was the most consistently reported mechanism for standing-related lower extremity symptoms.

Evidence suggests a detrimental association of prolonged standing with low back and lower extremity symptoms. To avoid musculoskeletal symptoms (without having a-priori knowledge on whether someone will develop symptoms or not), dose-response evidence

from this study suggests a recommendation to refrain from standing for prolonged periods >40 minutes. Interventions should also focus on underlying pain mechanisms.

Key words: Standing - Musculoskeletal symptoms – Systematic review – Exposure limit

Introduction

Prolonged periods of standing are traditionally common in certain occupations, including in retail, food, healthcare, education, and manufacturing industries. It has been shown that 62% of a sample from the general Australian working population reported their work involved standing[1]; which is consistent with findings from a study in a Canadian working population[2].

A growing body of evidence suggests that prolonged sitting is associated with several adverse health outcomes[3-5]. Consequently, expert recommendations advise workers to replace periods of sitting at work with standing and other light activities such as walking[6]. There is a growing interest in workplaces implementing this advice[7], most notably through the introduction of sit/stand office workstations[8]. However, these alternatives to sitting, such as standing, may expose workers to other health consequences[9].

Adverse health outcomes of standing have been previously reported[10], and include lower extremity venous disorders[11, 12], perinatal health complications (such as preterm delivery and pre-eclampsia)[13] and musculoskeletal symptoms (e.g. self-reported pain, discomfort or complaints in any region of the musculoskeletal system). In a recent systematic review on epidemiological evidence, it was identified (albeit from limited high quality evidence from longitudinal studies) that occupational standing was detrimentally associated with low back symptoms[14]. Evidence regarding the association of excessive standing and lower extremity symptoms was inconclusive, while of the limited evidence with upper extremity symptoms, a significant association did not seem to be evident.

One key issue inadequately addressed to date is the dosage of prolonged standing that may induce musculoskeletal symptoms. The prolonged standing strain index developed by Halim and Omar[15], which was based on a review of (scientific and professional)

occupational health literature and expert (e.g., ergonomic practitioners, medical doctors and physiotherapists) opinions, states that ≤1 hour of continuous standing can be considered safe, >1 hour of continuous standing is slightly unsafe and >1 hour of continuous standing in combination with >4 hours of standing per day as unsafe. The scientific basis of these exposure limits was, however, unclear as a systematic review of evidence on dose-response associations has not been undertaken.

Apart from the lack of understanding about exposure limits, underlying mechanisms explaining the associations of prolonged standing with musculoskeletal symptoms have not been elucidated. Such knowledge is needed for the development of interventions targeted at preventing detrimental effects of prolonged standing. Previous work has suggested mechanisms of muscle fatigue[16], static postures and lack of variation in movement[17, 18] to be possible contributors to standing-related low back symptoms. It has also been suggested that there may be different subgroups of people that do and do not develop low back symptoms during periods of prolonged standing[19-21]; often referred to as 'pain developers' and 'non-pain developers', respectively. However, factors that distinguish pain developers from non-pain developers are not well understood yet. For the association of standing and lower limb symptoms, mechanisms of muscle fatigue[22] and mechanisms from a non-musculoskeletal origin such as those of swelling[23] due to blood pooling in the lower limbs[16] have been suggested. However, a systematic overview of such mechanisms has not, as yet, been provided.

Considering the current emphasis on replacing office workplace sitting with standing, and the number of existing occupations that have traditionally been exposed to prolonged standing, a profound understanding of the health consequences of standing is needed to inform healthy work practices. Evidence-based exposure limits of standing are needed, while

an understanding of the mechanisms with regards to the association of prolonged standing and musculoskeletal symptoms is required. Our prior review of epidemiological studies examined the evidence of medium to long term dose-response relationships[14] but was not able to address acute dose-response relationships and contemporaneous potential mechanism changes. In this review we therefore aimed to: 1) systematically review the evidence on the acute associations between prolonged uninterrupted standing and non-specific musculoskeletal symptoms from controlled laboratory studies; 2) describe acute dose-response associations for standing and musculoskeletal symptoms to establish exposure limits; and, 3) tabulate potential mechanisms for these associations.

Methods

Search strategy

This review was a-priori registered[24] and executed according to the PRISMA statement guidelines[25]. To identify relevant publications, a comprehensive literature search was undertaken in electronic databases from database inception to 21 June 2016 using a combination of terms relevant to 'standing' and 'work-related' (Supplementary Material 1-6). No specific terms for health outcomes were used as this study is part of a larger review aimed at assessing the associations of standing with multiple health outcomes.

Two reviewers independently screened all potentially relevant titles and abstracts for eligibility, and if necessary, full-text articles were checked. Differences in judgment were resolved through a consensus procedure. Reference lists of selected articles were screened to identify additional potentially eligible articles. Studies were included if the article reported on the association of prolonged standing (defined for the purpose of this study as uninterrupted periods of standing for ≥20 minutes) with non-specific musculoskeletal

symptoms from a laboratory study; i.e., a controlled study which reported both the exposure to prolonged standing and musculoskeletal and possibly physiological outcomes (e.g., muscle activity, posture and leg circumference). We included articles published in English and in peer-reviewed journals. Reviews, editorials, letters and conference proceedings were excluded. Studies in which standing was not the main exposure variable (e.g., standing was only part of a certain condition/trial such as 'lifting during standing'), or in which standing was only used as a confounding variable, were excluded. Only articles describing a general adult population were included (e.g., excluding studies selecting workers with chronic disorders and non-adult populations). Moreover, for the purpose of this review, studies concerned with specific musculoskeletal conditions (e.g., osteoarthritis, fracture, cartilage damage) were excluded.

Data extraction and risk of bias assessment

Two reviewers independently assessed all selected articles for risk of bias and extracted relevant data. In cases of disagreement, consensus was reached during a meeting. Risk of bias was evaluated using an adapted version of a published methodological quality scoring system[26], based on eleven criteria for the reporting of study methods and results (Supplementary Material 7). Studies with a summary score ≥0.75 out of 1.00 were considered to be of high methodological quality[26], hence low risk of bias.

The following data from each included article were extracted: first author and year of publication, study design, sample description (i.e., number of participants, age, sex, country and other relevant specifics), standing condition (i.e., the duration of prolonged standing), other associated physiological outcomes (e.g., muscle activity, posture, spinal shrinkage, spinal load, leg circumference) and dose-response estimates. From articles reporting on

multiple conditions, only data from the prolonged standing condition were extracted. Where insufficient information was reported in the articles, authors were contacted to retrieve additional information. When dose-response information was otherwise unavailable, Digizeit software (Digizeit, Braunschweig, Germany, www.digitizeit.de) was used to digitize information on dose-response association from figures presented in the original articles.

Data-analysis

All included articles were qualitatively described according to their extracted data and risk of bias. Study findings were stratified according to the symptom body area.

Dose-response data from individual studies were plotted and statistically pooled using Microsoft Excel (Microsoft Corporation, Redmond USA). To do so, musculoskeletal symptom outcomes were harmonized by normalizing outcomes to a 100 point scale. A linear interpolation of the pooled dose-response was performed to estimate musculoskeletal symptom intensity with a given dosage of prolonged standing. To develop evidence-based exposure limits, the dosage of prolonged standing accompanying a clinical relevant musculoskeletal symptom intensity level of 9 (out of 100)[27] was estimated. As earlier study samples have been stratified into pain developers and non-pain developers[19-21], based on whether, a-posteriori, participant's symptoms exceeded or changed by more than a given threshold amount, the abovementioned procedure were repeated for: a) all participants (combining data from pain developers and non-pain developers, and using data from articles not distinguishing these two groups), and separately for b) pain developers and c) non-pain developers.

Potential mechanisms underlying the associations of prolonged standing with musculoskeletal symptoms were tabulated.

Results

Study selection

The flow chart of the search and selection of literature is presented in Figure 1. The search strategy yielded, after removing duplicates, 13,702 individual articles that were screened for inclusion. A total of 509 full text articles were considered, of which 296 met the criteria of describing outcomes of standing, 140 of them reporting on musculoskeletal symptoms. A total of 17 of these articles specifically addressed the association of prolonged standing and non-specific musculoskeletal symptoms using a laboratory study design. After screening the reference lists of these articles, nine more articles were added, resulting in a total of 26 articles[16-21, 23, 28-46] (reporting from 25 studies with 591 participants) included in the current review from which risk of bias assessment and data-extraction was conducted (see Supplementary Material 8 and 9 for a summary of findings).

Data extraction

All included articles described studies in which participants performed a laboratory static standing trial, while in ten studies participants[18, 20, 28, 32, 34-36, 38-40] additionally performed a light manual (e.g., clerical, assembly or precision) tasks for a prolonged period of time, averaging 107.5 (SD:40.9) minutes, ranging from 32 to 240 minutes. During these trials, musculoskeletal symptoms was self-reported, and in most of the studies, also other physiological outcomes (e.g., muscle activity, body postures or lower limbs swelling) were repeatedly objectively measured. Studied samples typically consisted of young and generally healthy participants without comorbidities such as pre-existing musculoskeletal symptoms

and/or other conditions that would prevent them from standing for a prolonged period of time. Participants also typically did not have any prior habituation to prolonged standing.

Identified articles reported musculoskeletal symptoms in the low back[17-21, 29-32, 35-43, 45] (19 articles), upper back[29] (two articles), trunk[44] (one article), neck/shoulder[44] (one article), and lower limbs[32] (one article), while various articles reported symptoms in specific areas of the lower limbs; i.e., thighs/buttocks[44], hips[29], upper legs[29], knees[29], lower legs[29, 33], ankles[29], feet[29, 32]. One article reported general symptoms (not in any specific body area)[34] while four articles measured and/or combined symptoms from various body areas[16, 23, 28, 46]. Thirteen articles assessed pain[17, 19, 21, 31, 35-43, 45], 10 articles assessed discomfort[16, 18, 20, 28, 29, 32, 33, 44, 46], one article assessed comfort[23] and one article assessed unpleasantness[34]. Musculoskeletal symptoms were assessed with self-reports using a visual analog scale (VAS) in 17 articles[17-21, 31-43], while five articles used a 0-10 scale[16, 28, 44-46], one article used a Borg scale[29] and one article used a 1-9 comfort rating scale[23].

Extracted studies showed consistent associations of prolonged standing with low back and lower extremity symptoms, with all identified studies showing symptom development (at least in a subgroup of the participants) during prolonged standing. However, inconsistent and limited study findings on other body area (e.g., upper limb) symptoms were found.

Thirteen articles categorized participants into pain developers and non-pain developers, using the following thresholds to make this categorization: one article used >10/100 symptoms intensity[21], one article used a change of >8/100[43] and two articles used a change >10/100 during the entire trial[19, 41], seven articles used a change >10/100 from the baseline score[17, 30, 31, 35-38, 40], one article used any change in symptoms during

the standing trial[42] and one article used symptoms intensity >20/100 at any point and >10/100 overall[39]. The prevalence of pain developers reported in the included articles ranged from 28%[41] to 71%[35], with an average of 44%.

Risk of bias

The average methodological quality score was 0.80 (SD:0.12) out of 1, ranging from 0.59 to 0.95, with 10 articles describing a study considered to have a high risk of bias (sum scores <0.75) (Supplementary Material 9).

Exposure limits for prolonged standing

Plots for the dose-response of prolonged standing and low back and lower extremity symptoms are shown in Figures 2-4 in which results of 18 articles are presented. As two papers reported on the same study data[18, 20], only data from one article was used for data pooling[18].

Information from five articles could not be pooled because: only symptoms[29] or change in symptoms[36] at the end of the trial were reported; or, no time series on symptoms were provided[37, 41, 42]. While the association of prolonged standing and upper extremity symptoms had been evaluated in some of the studies[16, 28, 39, 44], the articles did not report on any development of symptoms during their respective trials, hence no dose-response associations could be assessed. Two articles reported general musculoskeletal symptoms (not in any specific body area)[23, 46] and were therefore also not presented in the plots.

Dose-response associations from 14 articles on the association of prolonged standing and low back symptoms, for participants not differentiated into pain developers and non-

pain developers (Figure 2), show a gradual increase in low back symptoms during prolonged standing. The pooled dose-response association is depicted by:

*Symptoms = 0.12 * standing time + 0.66*

According to this equation, a clinical relevant symptom intensity of ≥9/100[27] would be achieved after 71 minutes of prolonged standing.

Stratified dose-response associations from the 10 different studies which provided data separately for pain developers (Figure 3) and non-pain developers (Supplementary Material 10) were plotted. The pooled dose-response association in the group of pain developers is depicted by:

*Symptoms = 0.20 * standing time + 0.52*

According to this equation, a clinical relevant symptom intensity of ≥9/100[27] would be achieved after 42 minutes of prolonged standing in pain developers.

The pooled dose-response association in the group of non-pain developers was depicted by:

*Symptoms = 0.02 * standing time + 0.31*

According to this equation, a clinical relevant symptom intensity of ≥9/100[27] would be achieved after 480 minutes (8 hours) of prolonged standing.

Finally, using data from six different articles[16, 28, 32-34, 44], the dose-response associations between prolonged standing and lower limb symptoms were plotted (Figure 4), showing an increasing pattern of lower limbs symptoms during prolonged standing. Due to the wide heterogeneity in associations (between studies), these data were not statistically pooled.

Mechanisms for musculoskeletal symptoms due to prolonged standing

Mechanisms for the development of low back and lower extremity symptoms due to prolonged standing are described in Tables 1 and 2 (from 17 and 10 studies, respectively). For low back symptoms, mechanisms at the level of the muscle, such as increased co-contraction, muscle fatigue or muscle stiffness, and a lack of muscle strength or endurance have been hypothesized to be a potential cause of low back symptoms. However, we could not find consistent evidence in supporting these mechanisms, with studies that did and did not find a significant association of these factors with either prolonged standing or the development of standing-related symptoms. We did however find consistency in evidence for mechanisms for the development of standing-related low back symptoms due to postures such as an increase in trunk flexion, axial rotation and lumbar curvature[18, 31, 42]. Evidence for a mechanism of (either too much or too little) variation in movement causing low back symptoms during standing showed a rather inconsistent picture with studies that did and did not find an association between factors like body sway, shifting of body weight and fidgeting with prolonged standing or the development of symptoms[16, 17, 29-32, 46].

For lower extremity symptoms, the mechanism of blood pooling during prolonged standing was most often reported. Consistent evidence showed that prolonged standing may cause an increase in blood flow (assessed by using Laser Doppler Flowmetry measured at the level of the skin), skin temperature and leg volume (typically assessed by measuring leg circumference), that may be associated with the development of musculoskeletal symptoms[16, 23, 28, 32-34, 45]. Evidence for mechanisms of (either too much or too little) variation in movement or muscle fatigue being the cause of standing-related lower-extremity symptoms showed a rather inconsistent picture with both studies that did and did not find an association of certain factors with prolonged standing or the development of symptoms.

Discussion

Prolonged standing and musculoskeletal symptoms

We have described the evidence on acute associations of prolonged standing and musculoskeletal symptoms from controlled laboratory studies. Prolonged standing was consistently associated with the development of low back and lower extremity symptoms in all identified studies reporting on these symptoms. There was inconsistent and limited evidence concerning risk for symptoms in other (e.g. upper extremity) areas. Our findings are broadly in line with what has been reported in earlier reviews[10, 14] showing the association of standing and musculoskeletal symptoms in epidemiological studies.

Importantly, our findings extend previous reports by quantifying the acute dose-response association between prolonged standing and low back symptoms. These findings were based on pooled dose-response associations of various studies from which data on low-back symptoms (i.e., pain and discomfort) were harmonized. In a general population (i.e. those not differentiated into pain developers and non-pain developers) it appeared that, a clinical relevant symptom intensity of ≥9/100 was evident after 71 minutes of prolonged standing, whereas such an intensity is reached after only 42 minutes in participants who develop pain. To minimize the risk of people developing musculoskeletal symptoms due to prolonged standing (without having a-priori knowledge on whether someone will develop symptoms or not), this information suggests ~40 minutes should be adopted as an exposure limit for prolonged standing. It should, however, be noted that even after a break from standing, symptoms are more likely to return in those that have developed standing-related symptoms prior to taking a break[47]. Care should thus be taken with applying the established threshold in those that have been exposed to earlier episodes of prolonged standing.

The dose-response associations of prolonged standing with lower extremity symptoms were substantially more heterogeneous than those for low back symptoms, as a result of which specific exposure limits for this body area were not determined. One possible reason for the heterogeneity could be the different areas of the lower extremity that were studied, with articles reporting lower limb symptoms in general[16, 32, 44], and symptoms in specific areas such as the feet[28, 32, 34], ankles[28] and lower legs[33].

An alternative approach to reducing the risk of developing standing-related musculoskeletal symptoms may be to distinguish pain developers from non-pain developers for more targeted intervention strategies. Specific groups of standing-related pain developers have been described[19-21], with an average prevalence of 44% in the study samples described in our review. The reliability and validity of the pain developer paradigm has been reported. Sorensen and colleagues described a number of symptoms that were reported by both standing-related pain developers and regular pain patients, thereby concluding to have found evidence for the validity of the paradigm[41]. Nelson-Wong and colleagues[37] showed high repeatability in identifying pain developing participants when tested four weeks apart. Our findings provide some guidance on identifying pain developers (Table 1). For example, pain developers showed to have a larger lumbar curvature[42] and a smaller hip range of motion[19] than non-pain developers. However, more information on the pain developer paradigm is needed to enable targeted intervention actions.

Mechanisms for the association of prolonged standing with musculoskeletal symptoms

Evidence on potential underlying mechanisms for the development of musculoskeletal symptoms due to prolonged standing was tabulated (Tables 1-2). Some consistency in the evidence for the postural mechanisms for the development of low back symptoms was

found with postures such as trunk flexion, axial rotation and lumbar curvature seemingly playing a role in the development of low back symptoms related to standing[18, 31, 42]. Such postures may induce an increase in lumbar load during prolonged standing[18], while the low back load during standing has already been shown to be higher than during sitting[48]. These elevated loads may play a role in the development of low back symptoms during prolonged standing.

For low back symptoms, mechanisms at the level of muscle, such as an increased co-contraction, muscle fatigue or stiffness, or a lack of muscle strength or endurance have been hypothesized to be a potential cause of low back symptom development. However, we only found limited, but inconsistent, evidence to support these mechanisms. Although variation in postures has often been suggested to be an important factor in the prevention of musculoskeletal symptoms[49], we identified only limited and inconsistent evidence supporting such a mechanism.

For lower extremity symptoms, although not necessarily musculoskeletal in nature, blood pooling in the lower extremities is one of the most often reported mechanisms for the adverse associations observed with prolonged standing. It has been shown previously that prolonged standing can increase intravascular hydrostatic venous pressure[50], whereas the lack of muscle pump action may contribute to venous stasis[50] and increased lower limb volume[23, 28, 45] which may put passive structures under stress, causing symptoms. Relatively consistent evidence showed that prolonged standing may cause an increase in blood flow, skin temperature and leg volume, providing funding for this mechanism. Evidence for mechanisms of variation in movement or muscle fatigue being the cause of standing-related lower-extremity symptoms was rather inconsistent, with both studies that

did and did not find an association between postural or muscle activity variables and either prolonged standing or the development of symptoms.

Implications for occupational health

Based on evidence examined in this review, it can be concluded that interventions to prevent standing-related musculoskeletal symptoms should aim at reducing prolonged standing time to below the evidence-based exposure limit suggested. However, interventions impacting on underlying mechanisms could also be considered. Such interventions may, for example, be directed at postures during standing or may be targeted at preventing lower limb blood pooling.

Various interventions for the prevention of standing-related musculoskeletal symptoms have been suggested, including those based on the notion that symptom development can be altered through postural modifications[31, 51] or movement[36]. These include breaking up prolonged standing by intermittent sitting[47] (to keep prolonged bouts below exposure limits) or by movement[52], or by applying certain shoe or floor conditions[53] (to address possible underlying mechanisms. However these interventions have generally only shown moderate effects on reducing symptoms so far[47, 52, 53]. In addition to health outcomes, interventions should also consider potential impact on work productivity to ensure they are feasible and sustainable.

Methodological considerations

Substantial evidence on the association of standing with musculoskeletal symptoms was found from laboratory studies, with data on physiological outcomes providing insight into possible mechanisms for the association. Although the evidence presented in this review

provides detailed information about the acute response to prolonged standing in a controlled situation, information on both the effect of long-term exposure to prolonged standing and/or responses to prolonged standing outside a laboratory setting is lacking. This includes a lack of information on, for example, more dynamic types of standing (as opposed to the predominantly static standing performed in laboratory settings), or standing that is broken up by bouts of other activities (e.g., sitting). Moreover, the described studies were typically conducted among groups of relatively healthy populations (i.e., young participants without comorbidities such as pre-existing musculoskeletal symptoms) (see information in Supplementary Material 8). As such, the current review findings cannot necessarily be extrapolated to other (more generic) populations. Some studies excluded participants from occupations that encompass substantial amounts of prolonged standing[28, 30, 31, 33]. Thus, at least for these studies, the findings from this review cannot be generalized to populations of workers that are habituated to prolonged standing. Therefore, it remains unknown whether dose-response associations differ for such populations as compared to the general population.

Regarding risk of bias, the majority of the articles in this systematic review did not control for relevant other (potentially confounding) factors. As a result of which, the role of socio-demographic (e.g., age and sex) and other (e.g., psychosocial or physical work demands) factors on the association of prolonged standing with musculoskeletal symptoms remains unknown. Moreover, most studies scored relatively low on the sample size, analytical methods used, and reporting data in sufficient detail. Such aspects should therefore deserve more attention in future work as they may underlie the lack of consistent findings for some of the aspects studied in our review.

No clear difference in dose-response associations could be obtained from studies reporting musculoskeletal pain compared to those reporting musculoskeletal discomfort (as per the dashed and solid lines in Figures 2-4). Such a difference was expected as earlier work had indicated that whilst they were strongly related, discomfort is more sensitive and develops earlier than pain in response to exposures to physical work demands[54]. This suggests participants in the various studies examined in this review perceived symptom intensity similarly regardless of whether pain or discomfort was the anchor term used.

Conclusion

This systematic review on laboratory studies found convincing evidence for a detrimental association between acute prolonged standing and development of musculoskeletal symptoms in the low back and lower extremities. We have reported on underlying mechanisms for these associations. Moreover, a safe exposure limit of 40 minutes of uninterrupted standing has been suggested before people typically develop clinically relevant levels of low back symptoms. This general exposure limit needs to considered in relation to other factors which may influence a worker's risk including prior exposure, unaccustomed to standing, older, and having comorbidities. Interventions should therefore be aimed at reducing prolonged standing time, below the provided exposure limit, or should focus on underlying pain mechanisms. Also interventions targeted at pain developers specifically should be developed.

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Author contribution

PC, LW, SP and JS conducted literature screening and data extraction of all included papers. LR and DB conducted the literature search in electronic data bases. All authors (PC, LW, SP, JS, LR, DB, GH, DD and LS) analysed the data and reviewed the manuscript for important intellectual content. LS is the study guarantor.

Figure 1. Flow chart depicting the literature selection procedure

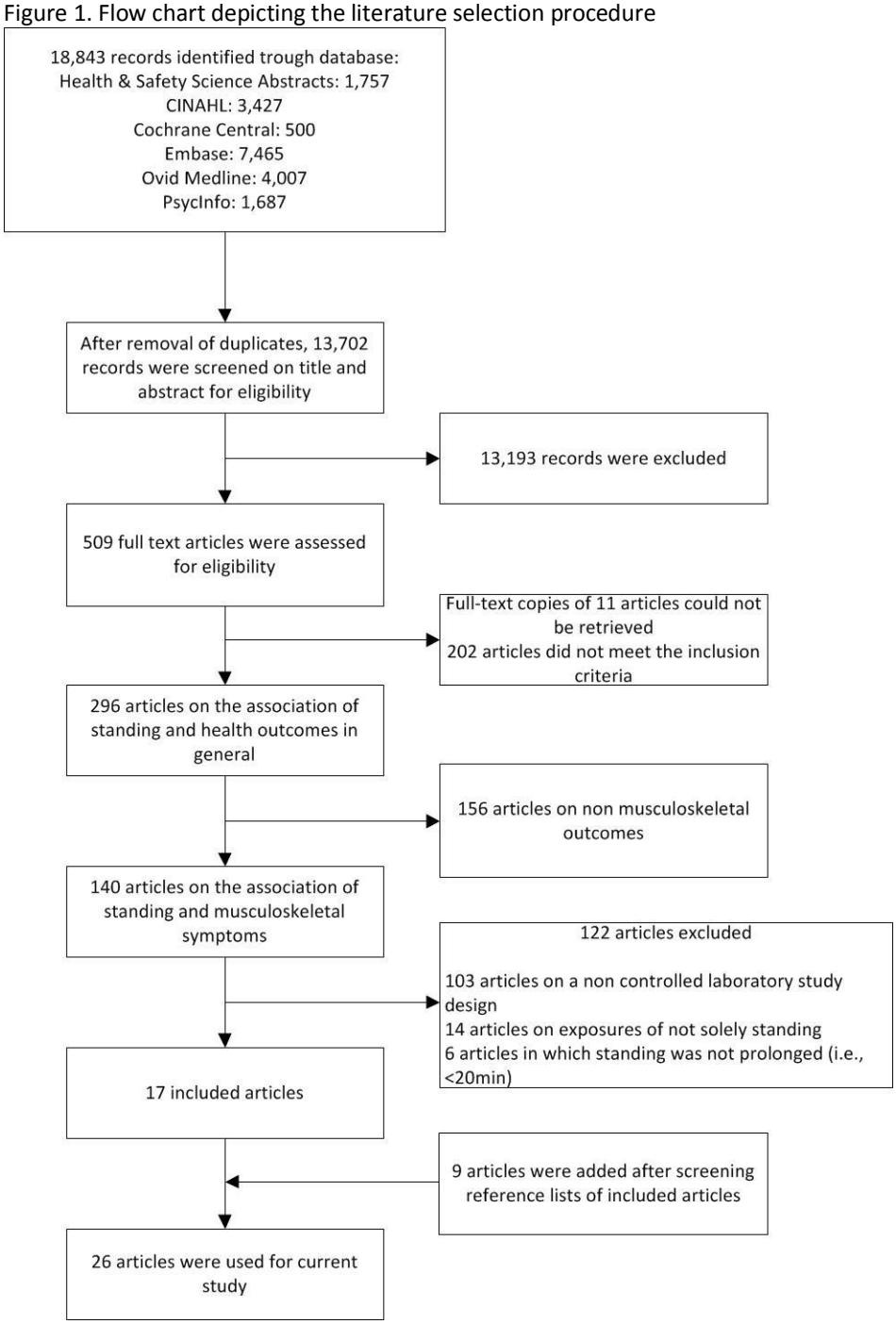

Figure 2. Dose-response of the association between prolonged standing (in minutes) and low back symptoms (i.e., pain or discomfort, on a 0 to 100 scale). Scores from articles reporting discomfort are depicting in dashed lines, while scores from articles reporting pain are depicted in solid lines. The thick grey line depicts the statistically pooled dose-response association.

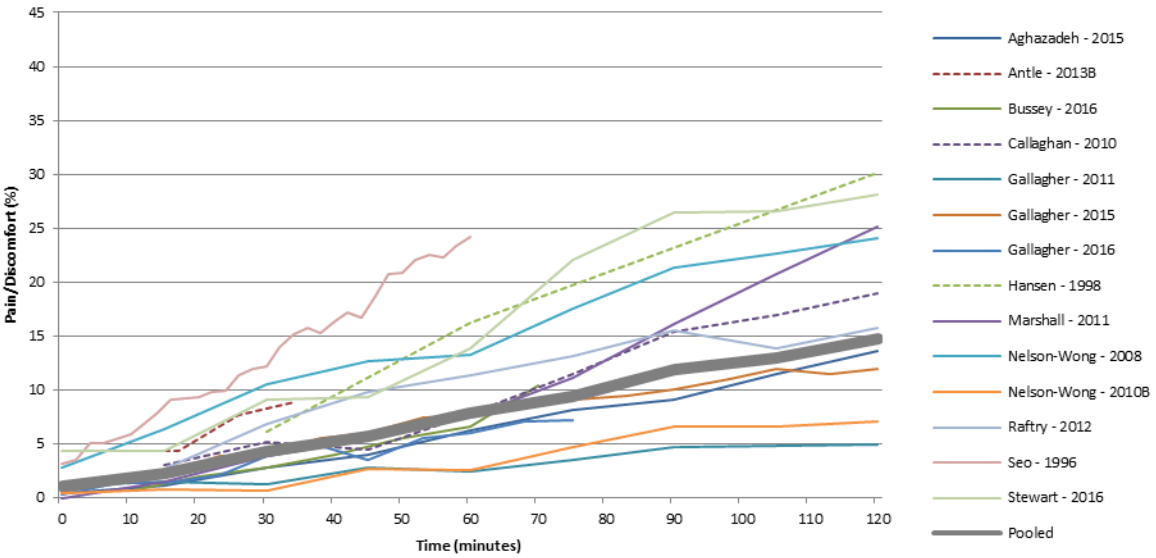

Figure 3. Dose-response of the association between prolonged standing (in minutes) and low back symptoms (i.e., pain or discomfort, on a 0 to 100 scale) in pain developers. Scores from articles reporting discomfort are depicting in dashed lines, while scores from articles reporting pain are depicted in solid lines. The thick grey line depicts the statistically pooled dose-response association.

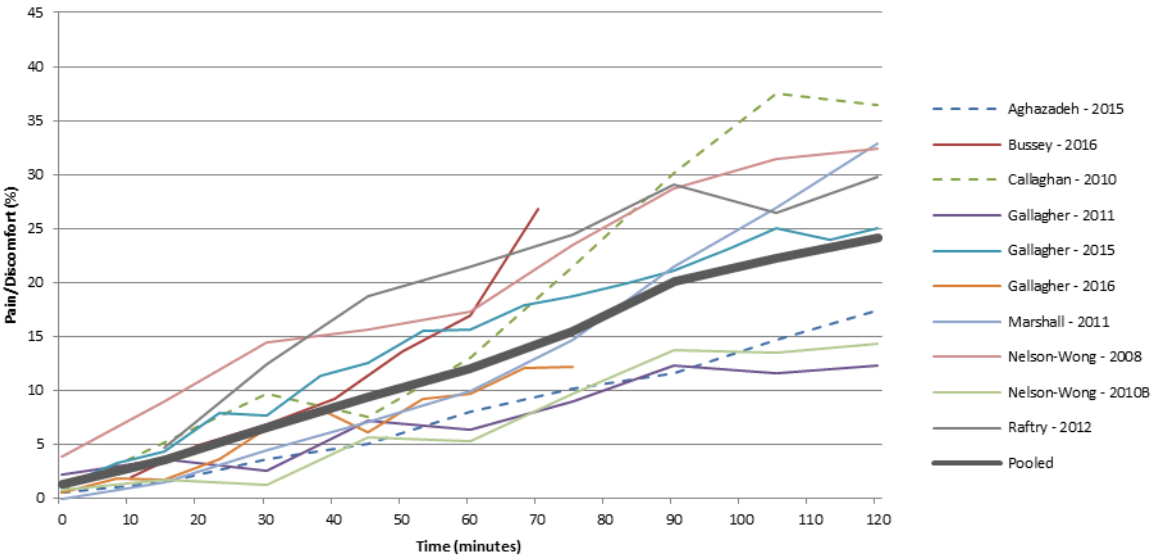

Figure 4. Dose-response of the association of prolonged standing (in minutes) and lower limb symptoms (i.e., pain or discomfort, on a 0 to 100 scale). Scores from articles reporting discomfort are depicting in dashed lines, while scores from articles reporting pain are depicted in solid lines.

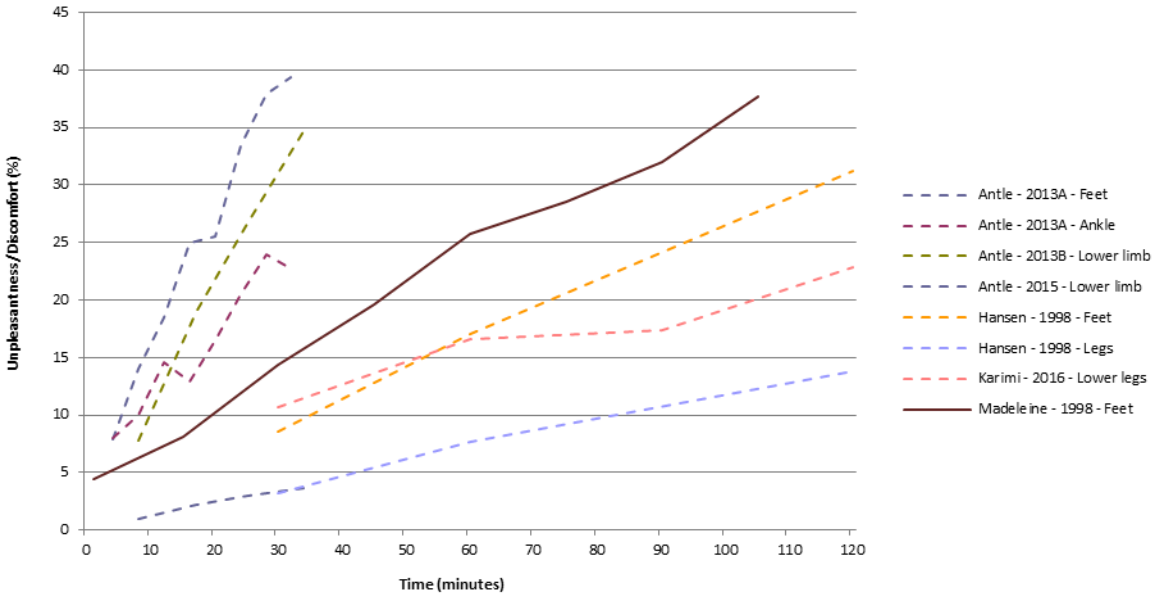

Table 1. Mechanisms for the association of prolonged standing and low back symptoms.

Possible mechanisms		**Evidence in favor**	**Evidence against**
Muscle	Co-contraction	• Higher gluteus medius co-contraction in PD* than in NPD[19, 21, 39] • Higher trunk co-contraction in PD than in NPD[39] • Gluteus medius co-contraction decreased during prolonged standing[19]	• No change in gluteus medius co-contraction during prolonged standing[21, 35, 39] • No change in change in trunk muscle co-contraction during prolonged standing[35, 39] • No difference in trunk muscle co-contraction between PD and NPD[39]
	Fatigue/ Oxygenation	• Increase in frequency of trunk muscle activity during prolonged standing[32]	• No change in trunk muscle activity during prolonged standing[16, 18, 32, 34, 44] • No association of trunk muscle activity and symptoms[29] • No change in muscle oxygenation during prolonged standing[18, 20] • No association of symptoms and muscle oxygenation[20]
	Strength	• Hip abductor muscle strength reduced after prolonged standing[35]	• No difference in gluteus medius muscle strength between PD and NPD[19]
	Endurance	• Hip abductor muscle endurance reduced after prolonged standing in PD[35]	• No difference in gluteus medius muscle endurance between PD and NPD[19]
	Stiffness	• Smaller hip range of motion in PD than NPD[19]	• No difference in hamstring stiffness, stretch tolerance and extensibility between PD and NPD[40]
Postural	Body sway	• Increase in sway during prolonged standing[16, 32, 46]	• No change in sway during prolonged standing[16, 30, 34] • No association between the number of weight shifts and symptoms[29]
	Lumbar posture	• Increase in lumbar flexion during prolonged standing[18, 31] • More spinal axial rotation with symptoms[18] • More lumbar curvature in PD than NPD[42] • More lumbar curvature with symptoms[42]	• No change in asymmetrical posture during prolonged standing[17]

	Posture (variation)	• Decrease in body weight shift frequency during prolonged standing[17] • Decrease[17] and increase[30] in body weight shift duration during prolonged standing • Increase in fidget amplitude during prolonged standing[17] • Higher[17] and lower[30, 31] fidget frequency in PD than NPD • Less spinal movement in PD than NPD[30] • More body shifts with symptoms[18] • Increase in postural changes during prolonged standing[46]	• No change in body weight shift amplitude during prolonged standing[17]
Loading	Lumbar load	• Increase in lumbar load during prolonged standing[18]	
Blood flow	Skin temperature	-	• No change in skin temperature during prolonged standing[18]
* PD = Pain developers NPD = Non-pain developers			

Table 2. Mechanisms for the prolonged standing and lower extremity symptoms.

Possible mechanisms		**Evidence in favor**	**Evidence against**
Blood pooling	Blood flow	• Increase in blood flow at the level of the foot[16, 28, 44] and the soleus muscle[28, 44] during prolonged standing • More blood flow and symptoms[16, 28]	• No increase in blood flow at the level of the soleus muscle during prolonged standing[16]
	Blood pressure	• Increase in blood pressure at the level of the ankle during prolonged standing[16, 28, 44]	• No change in blood pressure at the level of the ankle during prolonged standing[44]
	Skin temperature	• Increase in lower limb skin temperature during prolonged standing[32, 34] • More lower limb skin temperature with symptoms[29]	-
	Leg circumference/volume	• Increase in lower leg volume during prolonged standing[23, 32-34, 45] • More lower leg volume and symptoms[23]	• No association of lower limb volume and symptoms[29]
Muscle	Fatigue/ Oxygenation	• Increase in tibialis and gastrocnemius muscle activity during prolonged standing[16, 33]	• No change in lower limb muscle activity during prolonged standing[16, 28, 29, 34, 44, 46] • No association of lower limb muscle activity and symptoms[29]
Postural	Postures	• Increase in centre of gravity changes during prolonged standing[46]	• No change in centre of pressure movement during prolonged standing[34]
	Body sway	• Increase in sway during prolonged standing[16, 32, 46] • More number of weight shift with symptoms[29]	• No change in sway during prolonged standing[16, 34]

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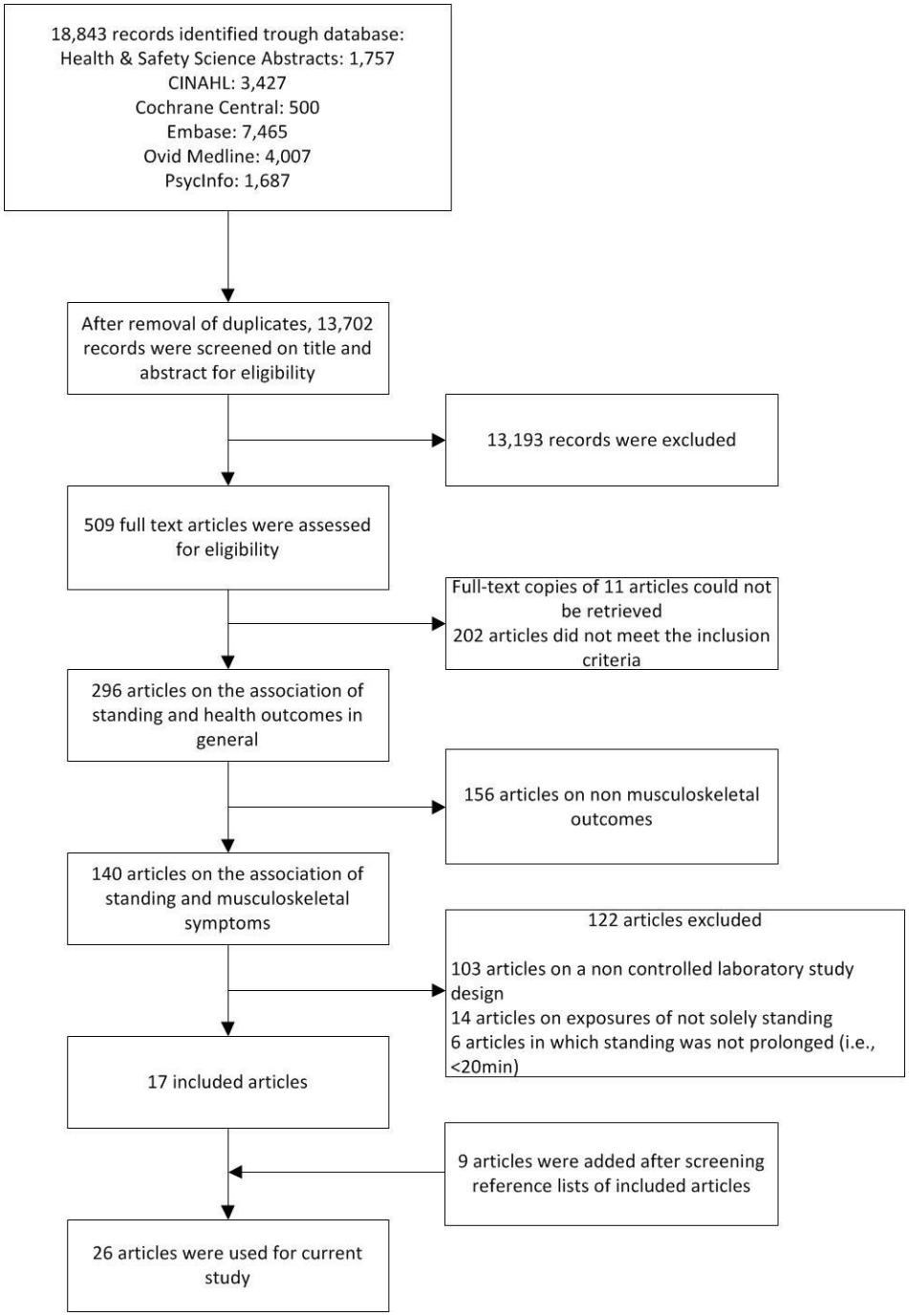
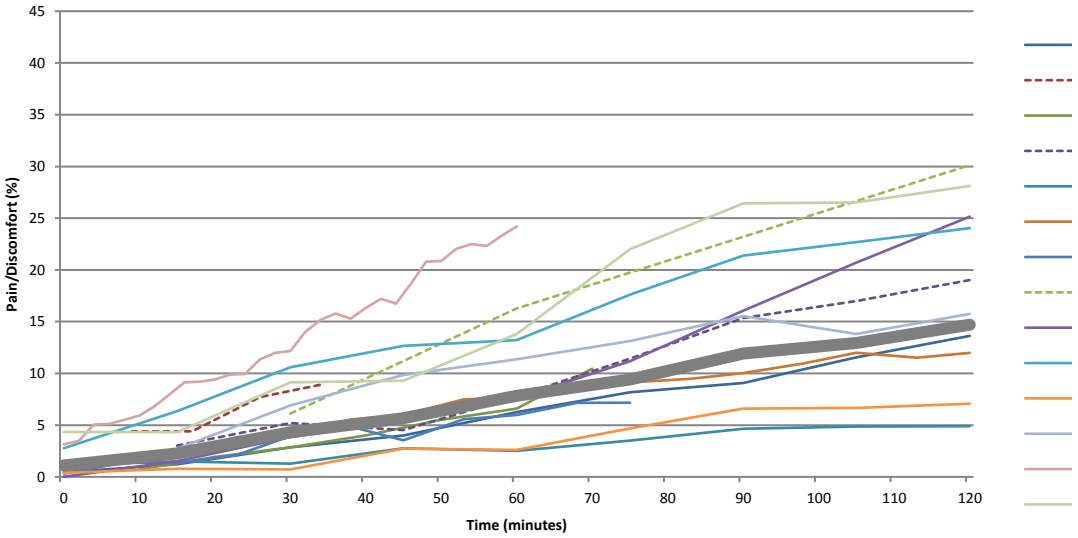

18,843 records identified trough database:
Health & Safety Science Abstracts: 1,757
CINAHL: 3,427
Cochrane Central: 500
Embase: 7,465
Ovid Medline: 4,007
PsycInfo: 1,687
After removal of duplicates, 13,702 records were screened on title and abstract for eligibility
13,193 records were excluded
509 full text articles were assessed for eligibility
Full-text copies of 11 articles could not be retrieved
202 articles did not meet the inclusion criteria
296 articles on the association of standing and health outcomes in general
156 articles on non musculoskeletal outcomes
140 articles on the association of standing and musculoskeletal symptoms
122 articles excluded
103 articles on a non controlled laboratory study design
14 articles on exposures of not solely standing
6 articles in which standing was not prolonged (i.e., <20min)
17 included articles
9 articles were added after screening reference lists of included articles
26 articles were used for current study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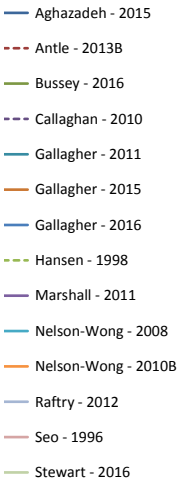
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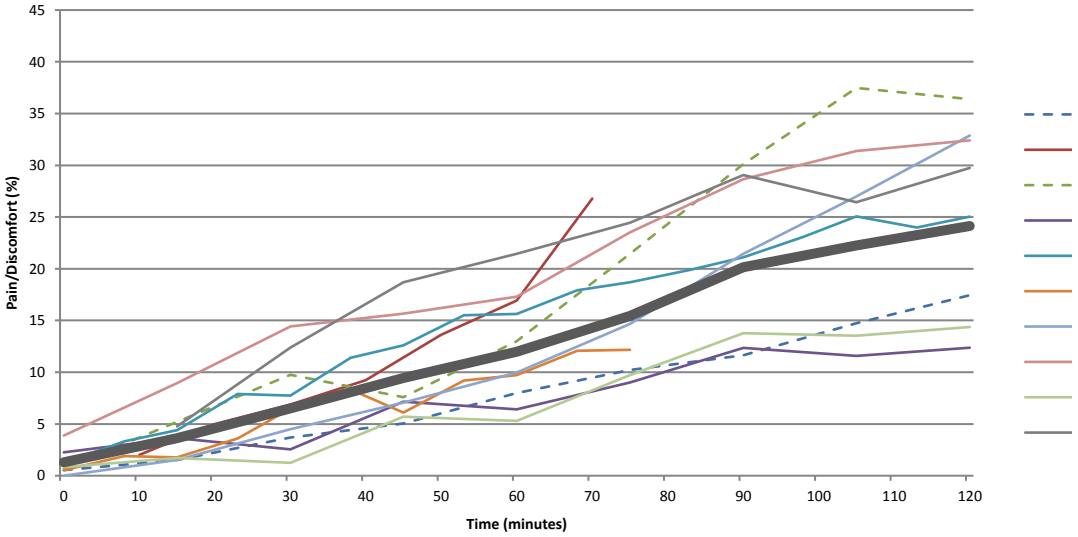
Seo - 1996
Stewart - 2016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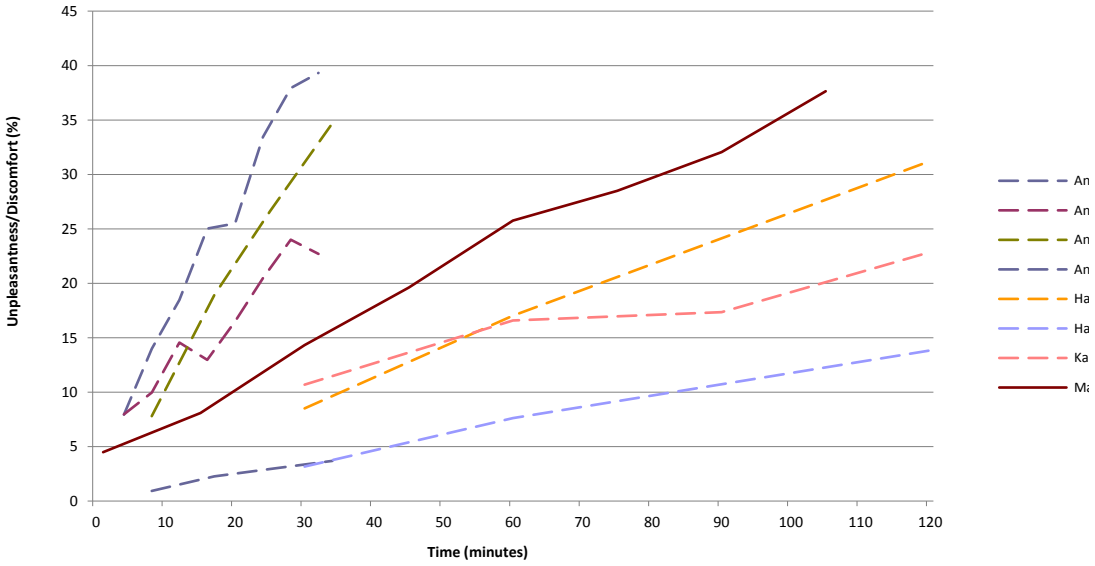
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ansen - 1998 - Legs

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Supplementary Material 1. Search strategy in Health & Safety Science Abstracts (ProQuest)

#	Search	Results
1	(((TI,AB,SU(Standing) AND TI,AB,SU(work* OR job* OR occupation* OR employee* OR staff* OR personnel OR ergonomic*)) OR (TI,AB,SU(posture* OR postural) AND TI,AB,SU(work* OR job* OR occupation* OR employee* OR staff* OR personnel OR ergonomic*)) OR (TI,AB,SU(stood OR stand) NEAR/3 TI,AB,SU(work* OR job* OR occupation* OR employee* OR staff* OR personnel OR ergonomic*)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(prolonged)) OR (TI,AB,SU(upright OR posture* OR stance) NEAR/3 TI,AB,SU(prolonged)) OR (TI,AB,SU(standing OR stand OR posture* OR stance) NEAR/2 TI,AB,SU(continuous)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(period*1)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/2 TI,AB,SU(time*1 OR duration)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(hour*1)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(day)))	
2	TI,AB,SU(trial OR trials OR study OR studies))	
3	1 and 2	
4	(((TI,AB,SU(Standing) AND TI,AB,SU(work* OR job* OR occupation* OR employee* OR staff* OR personnel OR ergonomic*)) OR (TI,AB,SU(posture* OR postural) AND TI,AB,SU(work* OR job* OR occupation* OR employee* OR staff* OR personnel OR ergonomic*)) OR (TI,AB,SU(stood OR stand) NEAR/3 TI,AB,SU(work* OR job* OR occupation* OR employee* OR staff* OR personnel OR ergonomic*)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(prolonged)) OR (TI,AB,SU(upright OR posture* OR stance) NEAR/3 TI,AB,SU(prolonged)) OR (TI,AB,SU(standing OR stand OR posture* OR stance) NEAR/2 TI,AB,SU(continuous)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(period*1)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/2 TI,AB,SU(time*1 OR duration)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(hour*1)) OR (TI,AB,SU(stood OR stand OR standing) NEAR/4 TI,AB,SU(day)))	
5	(TI,AB(random* OR quasirandom* OR placebo) OR TI,AB(single-blind OR double-blind OR triple-blind OR treble-blind)))	
6	4 and 5	
7	3 or 6	468

Supplementary Material 2. Search strategy in CINAHL Plus (EBSCO)

#	Search	Results
34	S28 AND S32 LIMIT: English Language	2,746
33	S28 AND S32	2,970
32	S29 OR S30 OR S31	1,142,504
31	(TI (study or studies)) OR (AB (study or studies))	786,316
30	(MH "Prospective Studies+") OR (MH "Case Control Studies+") OR (MH "Correlational Studies") OR (MH "Cross Sectional Studies") OR (MH "Double-Blind Studies") OR (MH "Panel Studies+") OR (MH "Single-Blind Studies") OR (MH "Triple-Blind Studies") OR (MH "Quasi-Experimental Studies+") OR (MH "Multicenter Studies") OR (MH "Qualitative Studies+") OR (MH "Multimethod Studies") OR (MH "Field Studies")	519,587
29	(MH "Clinical Trials+") OR (MH "Quantitative Studies") OR PT Clinical Trial OR TI (clinical trial*) OR AB (clinical trial*) OR TI random* or AB random*	281,256
28	S8 OR S10 OR S18 OR S27	6,128
27	S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26	406
26	((stood or stand or standing) N3 (period or periods)	68
25	(standing N2 (day or time or duration))	183
24	((stood or stand or standing) N4 (hour or hours))	42
23	((longterm or long-term or sustained) N0 standing)	2
22	(prolonged N2 (upright or posture))	29
21	(prolonged N0 (orthosta* or stance))	7
20	(continuous* N1 (stand or standing or posture*))	14
19	(prolonged N4 (stand or standing))	99
18	S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17	771
17	((occupation* or profession* or job* or employee* or staff* or personnel) N3 (posture* or postural*))	83
16	((profession or professions) N2 standing)	7
15	(work* N1 stand)	36
14	(work* N3 stood)	2
13	(work* N7 posture*)	453
12	((work* or job* or occupation*) N2 upright)	3
11	((work* or job* or occupation*) N6 standing)	244
10	S7 AND S9	1,888
9	TI standing or AB standing	8,598
8	S1 AND S7	3,976
7	S2 OR S3 OR S4 OR S5 OR S6	981,422
6	(MH "Ergonomics") OR (MH "Task Performance and Analysis")	13,274
5	(MH "Absenteeism") OR (MH "Sick Leave") OR (MH "Retirement") OR (MH "Job Satisfaction") OR (MH "Job Performance")	28,005
4	(MH "Work") OR (MH "Work Environment") OR (MH "Work Capacity Evaluation") OR (MH "Work Experiences") OR (MH "Workload Measurement") OR (MH "Workload") OR (MH "Shiftwork") OR (MH "Women, Working+") OR (MH "Workforce") OR (MH "Shift Workers")	46,833
3	(MH "Occupations and Professions") OR (MH "Health Occupations+") OR (MH "Named Groups by Occupation+") OR (MH "Employment") OR (MH "Employment of Women") OR (MH "Employment of Older Workers") OR (MH "Employment Status") OR (MH "Part Time Employment")	914,979
2	(MH "Occupational Diseases") OR (MH "Occupational-Related Injuries") OR (MH "Occupational Exposure") OR (MH "Accidents, Occupational") OR (MH "Occupational Hazards") OR (MH "Occupational Health") OR (MH "Occupational Health Services") OR (MH "Occupational Medicine") OR (MH "Occupational Safety") OR (MH "Occupational Science")	53,568
1	(MH "Standing+") OR (MH "Posture") OR (MH "Balance, Postural")	18,531

Supplementary Material 3. Search strategy in EBM Reviews - Cochrane Central Register of Controlled Trials

#	Search	Results
1	postural balance/ or posture/	3,766
2	occupational diseases/ or occupational exposure/ or occupational health/ or occupational medicine/ or Occupational Injuries/ or Occupational Health Services/ or Accidents, Occupational/	1,473
3	Health Occupations/ or Occupations/ or exp occupational groups/ or exp Employment/	6,697
4	work/ or work schedule tolerance/ or workload/ or workplace/ or Women, Working/ or Work Capacity Evaluation/ or Work Simplification/	1,062
5	Absenteeism/ or Sick Leave/ or Retirement/ or Job Satisfaction/	818
6	Human Engineering/ or ergonomic*.tw.	513
7	2 or 3 or 4 or 5 or 6	8,967
8	1 and 7	150
9	standing.ti. or standing.ab. /freq=2	1,286
10	7 and 9	36
11	((standing adj4 (posture* or position)) and (work* or job* or occupation* or employee* or staff* or ergonomic* or personnel)).mp.	50
12	((work* or job* or occupation*) adj7 standing).tw.	58
13	((work* or job* or occupation*) adj3 upright).tw.	8
14	(work* adj8 posture*).tw.	90
15	(work* adj4 stood).tw.	0
16	(work* adj2 stand).tw.	13
17	(profession*1 adj3 standing).tw.	7
18	((occupation* or profession* or job* or employee* or staff* or personnel) adj4 (posture* or postural*)).tw.	19
19	12 or 13 or 14 or 15 or 16 or 17 or 18	169
20	(prolonged adj5 (stand or standing)).tw.	28
21	(continuous* adj2 (stand or standing or posture*)).tw.	8
22	(prolonged adj (orthosta* or stance)).tw.	3
23	(prolonged adj3 (upright or posture)).tw.	7
24	((longterm or long-term or sustained) adj standing).tw.	0
25	((stood or stand or standing) adj5 hour*1).tw.	85
26	(standing adj2 (day or time or duration)).tw.	97
27	((stood or stand or standing) adj4 period*1).tw.	75
28	20 or 21 or 22 or 23 or 24 or 25 or 26 or 27	287
29	8 or 10 or 11 or 19 or 28	581
30	limit 29 to english language	468

Supplementary Material 4, search strategy in Embase (Ovid)

#	Search	Results
1	body posture/ or standing/	63,339
2	occupational disease/ or occupational health/ or occupational exposure/ or occupational hazard/ or occupational health service/ or occupational safety/ or occupational accident/ or occupational medicine/ or industrial medicine/	190,792
3	occupation/ or medical profession/ or nursing as a profession/ or paramedical profession/ or exp named groups by occupation/ or exp employment/	1,327,430
4	work/ or work schedule/ or working time/ or workload/ or work capacity/ or work environment/ or work experience/ or workplace/	113,731
5	absenteeism/ or job satisfaction/ or medical leave/ or retirement/	48,686
6	ergonomics/	8,684
7	2 or 3 or 4 or 5 or 6	1,534,465
8	1 and 7	7,055
9	standing.ti. or standing.ab. /freq=2	16,406
10	7 and 9	1,458
11	((standing adj4 (posture* or position)) and (work* or job* or occupation* or employee* or staff* or ergonomic* or personnel)).mp.	692
12	((work* or job* or occupation*) adj7 standing).tw.	1,069
13	((work* or job* or occupation*) adj3 upright).tw.	37
14	(work* adj8 posture*).tw.	1,752
15	(work* adj4 stood).tw.	22
16	(work* adj2 stand).tw.	97
17	(profession*1 adj3 standing).tw.	28
18	((occupation* or profession* or job* or employee* or staff* or personnel) adj4 (posture* or postural*)).tw.	249
19	12 or 13 or 14 or 15 or 16 or 17 or 18	2,942
20	(prolonged adj5 (stand or standing)).tw.	438
21	(continuous* adj2 (stand or standing or posture*)).tw.	92
22	(prolonged adj (orthosta* or stance)).tw.	65
23	(prolonged adj3 (upright or posture)).tw.	129
24	((longterm or long-term or sustained) adj standing).tw.	27
25	((stood or stand or standing) adj5 hour*1).tw.	389
26	(standing adj2 (day or time or duration)).tw.	1,018
27	((stood or stand or standing) adj4 period*1).tw.	477
28	20 or 21 or 22 or 23 or 24 or 25 or 26 or 27	2,431
29	8 or 10 or 11 or 19 or 28	12,029
30	limit 29 to (clinical trial or randomized controlled trial or controlled clinical trial or multicenter study)	552
31	(random* or quasirandom* or trial or trials or placebo).tw. or clinical trial*.mp.	2,003,888
32	cohort analysis/ or case control study/ or longitudinal study/ or prospective study/ or retrospective study/	896,544
33	observational study/ or quasi experimental study/ or clinical study/ or intervention study/ or prevention study/	199,113
34	crossover procedure/ or controlled study/ or randomization/	4,565,179
35	((single or double or triple or treble) adj (blind* or mask*)).tw.	170,885
36	(study or studies).tw.	805,8649
37	31 or 32 or 33 or 34 or 35 or 36	1,103,7922
38	29 and 37	7,344
39	30 or 38	7,344
40	exp animal/ not human.sh.	4,480,661
41	39 not 40	6,923
42	limit 41 to english language	6,290

Supplementary Material 5. Search strategy in Ovid MEDLINE.

#	Search	Results
1	postural balance/ or posture/	66,510
2	occupational diseases/ or occupational exposure/ or occupational health/ or occupational medicine/ or Occupational Injuries/ or Occupational Health Services/ or Accidents, Occupational/	164,970
3	Health Occupations/ or Occupations/ or exp occupational groups/ or exp Employment/	500,223
4	work/ or work schedule tolerance/ or workload/ or workplace/ or Women, Working/ or Work Capacity Evaluation/ or Work Simplification/	50,324
5	Absenteeism/ or Sick Leave/ or Retirement/ or Job Satisfaction/	37,021
6	Human Engineering/ or ergonomic*.tw.	12,042
7	2 or 3 or 4 or 5 or 6	675,628
8	1 and 7	3,706
9	standing.ti. or standing.ab. /freq=2	12,325
10	7 and 9	579
11	((standing adj4 (posture* or position)) and (work* or job* or occupation* or employee* or staff* or ergonomic* or personnel)).mp.	435
12	((work* or job* or occupation*) adj7 standing).tw.	734
13	((work* or job* or occupation*) adj3 upright).tw.	30
14	(work* adj8 posture*).tw.	1,239
15	(work* adj4 stood).tw.	16
16	(work* adj2 stand).tw.	71
17	(profession*1 adj3 standing).tw.	17
18	((occupation* or profession* or job* or employee* or staff* or personnel) adj4 (posture* or postural*)).tw.	173
19	12 or 13 or 14 or 15 or 16 or 17 or 18	2,058
20	(prolonged adj5 (stand or standing)).tw.	291
21	(continuous* adj2 (stand or standing or posture*)).tw.	67
22	(prolonged adj (orthosta* or stance)).tw.	51
23	(prolonged adj3 (upright or posture)).tw.	104
24	((longterm or long-term or sustained) adj standing).tw.	18
25	((stood or stand or standing) adj5 hour*1).tw.	280
26	(standing adj2 (day or time or duration)).tw.	739
27	((stood or stand or standing) adj4 period*1).tw.	346
28	20 or 21 or 22 or 23 or 24 or 25 or 26 or 27	1,749
29	8 or 10 or 11 or 19 or 28	7,017
30	(controlled clinical trial or randomized controlled trial).pt.	467,024
31	(random* or quasirandom* or trial or trials or placebo).tw. or clinical trial*.mp.	1,395,354
32	case-control studies/ or retrospective studies/ or cohort studies/ or longitudinal studies/ or follow-up studies/ or prospective studies/ or cross-sectional studies/ or epidemiologic studies/ or intervention studies/	1,693,552
33	control groups/ or cross-over studies/ or double-blind method/ or random allocation/ or single-blind method/	239,123
34	((case-control or cross-sectional or cohort* or (follow-up or followup or observational or longitudinal or prospective or retrospective or epidemiologic* or intervention* or incidence or prevalence)) adj (study or studies)).tw.	566,533
35	((single or double or triple or treble) adj (blind* or mask*)).tw.	124,949
36	case reports/ or comparative study/ or evaluation studies/ or multicenter study/ or twin study/ or validation studies/	3,709,309
37	(comparative study or evaluation studies or multicenter study or observational study or validation studies).pt.	2,021,391
38	(study or studies).tw.	5,922,027
39	30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38	9,419,258
40	29 and 39	4,408
41	exp animals/ not humans.sh.	3,982,927
42	40 not 41	4,103
43	limit 42 to english language	3,606

Supplementary Material 6. Search strategy in PsycINFO. (Ovid)

#	Searches	Results
1	posture/	4,286
2	occupational exposure/ or occupational health/ or occupational safety/ or work related illnesses/ or industrial accidents/	5,846
3	exp personnel/ or occupations/ or working women/ or exp employment status/	344,148
4	working conditions/ or work scheduling/ or work load/ or workday shifts/ or working space/ or job characteristics/ or work rest cycles/	26,709
5	job satisfaction/ or job performance/ or employee productivity/ or employee characteristics/ or productivity/ or employee efficiency/ or Employee Absenteeism/	36,744
6	Human Factors Engineering/ or ergonomic*.tw.	7,220
7	2 or 3 or 4 or 5 or 6	382,120
8	1 and 7	441
9	standing.ti. or standing.ab. /freq=2	2,209
10	7 and 9	198
11	((standing adj4 (posture* or position)) and (work* or job* or occupation* or employee* or staff* or ergonomic* or personnel)).mp.	89
12	((work* or job* or occupation*) adj7 standing).tw.	412
13	((work* or job* or occupation*) adj3 upright).tw.	3
14	(work* adj8 posture*).tw.	379
15	(work* adj4 stood).tw.	9
16	(work* adj2 stand).tw.	53
17	(profession*1 adj3 standing).tw.	12
18	((occupation* or profession* or job* or employee* or staff* or personnel) adj4 (posture* or postural*)).tw.	61
19	12 or 13 or 14 or 15 or 16 or 17 or 18	885
20	(prolonged adj5 (stand or standing)).tw.	41
21	(continuous* adj2 (stand or standing or posture*)).tw.	12
22	(prolonged adj (orthosta* or stance)).tw.	5
23	(prolonged adj3 (upright or posture)).tw.	15
24	((longterm or long -term or sustained) adj standing).tw.	4
25	((stood or stand or standing) adj5 hour*1).tw.	33
26	(standing adj2 (day or time or duration)).tw.	189
27	((stood or stand or standing) adj4 period*1).tw.	56
28	20 or 21 or 22 or 23 or 24 or 25 or 26 or 27	334
29	8 or 10 or 11 or 19 or 28	1,659
30	clinical trials/ or cohort analysis/ or followup studies/ or longitudinal studies/ or retrospective studies/ or prospective studies/ or experimentation/ or interdisciplinary research/ or qualitative research/ or quantitative methods/ or causal analysis/ or exp experimental methods/ or exp experimental design/	118,841
31	random sampling/ or experiment controls/	1,406
32	(random* or quasirandom* or trial or trials or placebo).tw. or clinical trial*.mp.	240,824
33	((single or double or triple or treble) adj (blind* or mask*)).tw.	20,454
34	(study or studies).tw.	1,442,328
35	30 or 31 or 32 or 33 or 34	1,608,930
36	29 and 35	923
37	limit 29 to ("0200 clinical case study" or "0400 empirical study" or "0430 followup study" or "0450 longitudinal study" or "0451 prospective study" or "0453 retrospective study" or "0600 field study" or 1400 nonclinical case study or 1600 qualitative study or 1800 quantitative study or 2200 twin study)	1,080
38	36 or 37	1,245
39	limit 38 to english language	1,210

Supplementary Material 7. Methodological quality scale for the assessment of risk of bias.

	Criteria	**Yes (2)**	**Partial (1)**	**No (0)**	**N/A**
1.	Question / objective sufficiently described?				
2.	Study design evident and appropriate?				
3.	Method of subject/comparison group selection *or* source of information/input variables described and appropriate?				
4.	Subject (and comparison group, if applicable) characteristics sufficiently described?				
5.	Outcome and (if applicable) exposure measure(s) well defined and robust to measurement / misclassification bias? Means of assessment reported?				
6.	Sample size appropriate?				
7.	Analytic methods described/justified and appropriate?				
8.	Some estimate of variance is reported for the main results?				
9.	Controlled for confounding?				
10.	Results reported in sufficient detail?				
11.	Conclusions supported by the results?				
	Summary score				

Note, N/A is not a response option for items for items 1, 2, 4m 10 and 11. The summary score was calculated as: total sum[(number of 'yes' × 2) + (number of 'partial' × 1)]/total possible sum[22 − (number of 'N/A' × 2)], with a maximum possible total score of 1.

Supplementary Material 8. Data extraction table of included articles.

	First author; Year	Sample (n, % female, age, country and other relevant sample specifics)	Standing condition	Symptoms (pain /discomfort)	Physiological outcomes	Results
1	Aghazadeh; 2015[22]	n=15 %female: 0% Age: PD 22(0.56) years and NPD 22.8(1.36) years. Country: Iran Other specifics: Participants who could stand for >4 hours were selected. Individuals with a history of low back pain in the last 12 months (requiring medication or sickness absence) were excluded.	Participants stood for 2 hours on a normal firm surface[1]. Relevant variables were measured every 15 minutes.	A VAS (ranging from 0 to 100mm) was used to assess low back pain. Participants were classified into PDs (those with maximum VAS scores >10mm) and NPD	Bilateral muscle activity of the gluteus medius muscle, assessing co-contraction.	Ten (67%) of the participants were considered PD. Low back pain increased significantly during standing Gluteus medius co-contraction did not change during standing. Hover values were significantly higher in PD compared to NPD.
2	Antle; 2013A[29]	n=10 %female: 100% Age: 22.8 (3.8) years; Country: Canada Other specifics: Asymptomatic, not employed in standing jobs	Participants stood bare-feet on a 2mm thick carpet that was placed on a concrete floor for 32 minutes. Relevant variables were collected every 4 minutes	Discomfort in several body regions (as specified by the participants) was assessed using a scale with numerical values between 0 and 10. Only body areas with >50% of the participants reporting discomfort were analysed.	Muscle activity of the right and left lumbar erector spinae and rectus abdominis. Cutaneous blood flow at the level of the soleus muscle and metatarsal (measured by using Laser Doppler Flowmetry). Heart rate and blood pressure at the level of the ankle	Discomfort in the feet and knees was significantly higher from minute 12 onwards compared to minute 4 (with the exception of knee discomfort at minute 16). Blood volume flow in feet and soleus was significantly higher from minute 24 onwards compared to minute 4. There was a strong correlations between the blood flow and lower limb discomfort. Blood pressure in the ankles was significantly higher from minute 8 onwards compared to minute 4 No significant changes in muscle activity and heart rate were observed.
3	Antle; 2013B[17]	n=18 %female: 44% Age: 32.4(8.2) years Country: Canada Other specifics: Asymptomatic	Participants stood bare-feet on a 2 mm rubber carpet for 34 minutes (in 4 bouts of 8.5 minutes) during which participants constructed a box. Variables were measured after every 8.5 minute.	Discomfort in several body regions (as specified by the participants) was assessed using a scale with numerical values between 0 and 10.	Muscle activity of tibialis anterior, soleus, gastrocnemius, gluteus medius, rectus abdominis, external oblique and lumbar erector spinae, assessing RMS activity and cross-correlations (to obtain a value for co-activation between trunk flexors and extensors).	Fifteen participants (83%) reported discomfort in the feet or lower limb and 5 (28%) in the back at some point during the trial. Discomfort in these areas significantly increased over time. Muscle activity amplitude of the tibialis anterior and gastrocnemius significantly decreased while standing after the

		participants were selected.			Skin blood flow at the level of the distal soleus and the 4th foot metatarsal Lower limb blood pressure at the level of the ankle (measured by using Laser Doppler Flowmetry). Body centre of pressure sway in anterior-posterior and medio-lateral direction were obtained from force plate measurements.	second measurement and maintained its values during the rest of the trial. There were no changes in activity of the soleus or any of the trunk or hip muscles, nor in the co-activation. Skin blood flow at the foot increased significantly to 126% of its baseline value. No changes in blood flow at the level of the soleus were found. Ankle blood pressure significantly increased (already after 17 minutes) and maintained its high value during the rest of the trial. Centre of pressure sway increased significantly in medio-lateral direction, but not in anterior posterior direction. Lower limb discomfort was significantly correlated with skin blood flow in the foot
4	Antle; 2015[45]	n=15 %female: 7 females (47%) Age: 32.4 (8.7) years Country: Canada Other specifics: Asymptomatic, non-pregnant participants without a history of neurological, musculoskeletal or vascular disorders during the past year were selected.	Participants stood for 34 minutes in 4 bouts of 8.5 minutes[1]. Relevant variables were measured before and after every 8.5 minute (with the exception of muscle activity that was measured every 4 minutes).	Discomfort of the trunk, neck/shoulder and lower limbs was measured using a scale from 0 (no discomfort) to 10 (unbearable discomfort).	Muscle activity of the bilateral gluteus medius, rectus abdominis, external oblique and lumbar erector spinae, as well as the right trapezius and deltoid muscles, assessing root-mean-square muscle activity and co-contraction. Skin blood flow at the level of the soleus and foot (measured by using Laser Doppler Flowmetry). Blood pressure at the level of the ankle.	Discomfort in the lower limbs and low back increased significantly over time. No significant change in neck/shoulder discomfort over time were observed, and no participants reported discomfort in the buttocks/thighs. There was a significant increase in blood flow over time. No changes in any of the other physiological outcomes were observed.
5	Bussey; 2016[20]	n= 39 %female: 100% Age: PD 19.31 (1.44) years and NPD 20.04 (1.67) years. Country: New Zealand	Participants stood for 70 minutes Relevant variables were measured every 10 minutes.	Low back pain was measured with a VAS ranging from 0 ('no pain') to 100mm ('the worst pain imaginable'). Participants who changed >10mm on the VAS were considered PD.	Gluteus medius activity assessing co-activation. Only before the standing trial, gluteus medius strengths, endurance and range of motion were assessed.	Fourteen participants (36%) were considered PD (of which 11 with and 3 without a history of pain). Out of the 25 NPD, 3 had a history of pain). Low back pain increased over time and was significantly different between PD and NPD. Hip range of motion was significantly

		Other specifics: Field hockey players (premier level) with (n=14) and without (n=25) a history of low back pain were selected. Participants without a history of pain did not have any acute or subacute episode of pain in the last 24 months or chronic pain or spinal morphologies (e.g. fractures, ruptures or surgery)				lower in PD but gluteus medius strength and endurance did not differ between the two groups. Gluteus medius co-activation decreased significantly over time. Values were higher in PD compared to NPD, but there were no differences in the pain scores over time between the two groups (interaction effect).
6	Callaghan; 2010[21]	n=16 (participants who participated in standing protocol) %female: 50% Age: 25.1(2.1) (males), 23.5(2.3) (females) Country: Canada Other specifics: Participants free of low back disorders in the last 12 months were selected	Participants stood for 2 hours (wearing their own shoes) while performing four precision tasks. Relevant variables were measured every 15 minutes	Perceived low back discomfort was assessed using a 100mm VAS (0=no discomfort at all, 100=worst discomfort imaginable) The 6 participants with the highest low back discomfort and 6 participants with the lowest low back discomfort were analysed separately.	Near infrared spectroscopy was used to assess muscle oxygenation of the erector spinae at L3 level.	Low back discomfort significantly increased over time with a mean increase of 21.1(19.5)mm No change in muscle oxygenation over time was observed. However, when participants with high and low levels of low back discomfort were analysed separately, there was a change in muscle oxygenation over time for the low low back discomfort participants. There was no correlation between discomfort and muscle oxygenation.
7	Cham; 2001[30]	n=10 %females :50% Age: 27(6) years Country: USA Other specifics: Participants with no history of lower-extremity or back problem were selected	Participants stood for four hours on a hard floor wearing the same footwear[1]. Discomfort was measured every 30 minutes while other relevant variables were measured every 15-20 minutes.	Discomfort (in upper and lower back, hips, upper legs, knees, lower legs, ankles and feet) and fatigue (overall fatigue and leg fatigue) were assessed using a CR10 Borg scale (ranging from 6 to 20).	Lateral displacement of the centre of pressure was assessed using a force platform. Muscle activity of the tibialis anterior, soleus and erector spinae muscles, assessing median frequency shifts. Skin temperature at the level of the soleus, tibialis anterior, quadriceps and hamstring muscles Leg volume (up to the level of the tibial plateau) was measured using a water tank displacement method	A significant correlation was found between the number of centre of pressure weight shifts (for hours 3 and 4) and skin temperature, and discomfort/fatigue in the lower limbs. No significant associations of the other physiological outcomes with discomfort/fatigue were observed.
8	Chester; 2002[24]	n=18 %females: 39% Age: 21.9 years	Participants stood for 90 minutes on a floor mat wearing sneakers.	Comfort in the upper back, lower back, hips, upper legs, knees, lower legs, ankles and feet was measured every 30 minutes, using a comfort rating chart (ranging from 1 to 9, with 9 being	Impedance in of the skin of the at the level of the calf muscles was measured every 5 minutes, assessing the volume of the lower leg Calf diameter was measured every 9	Overall, comfort decreased over time. Overall tiredness increased over time Leg volume increased 38.2 cm^3 and calve circumference increase 1.7% over time.

		Country: USA Other specifics: Participants without previous lower extremity or back problems were selected.		very comfortable) Overall tiredness was measured using a VAS	minutes	 Change in lower leg volume was negatively correlated with upper back, lower back, and hip comfort. Change in calf circumference is positively correlated with ankle and foot comfort.
9	Gallagher; 2011[18]	n=40 %female: 50% Age: 24.4 (2.9) years Country: Canada Other specifics: Participants without a history of low back pain requiring medical treatment or resulting in >3 days off school/work were selected	Participants stood for two hours Relevant variables were measured every 15 minutes.	Low back pain was assessed using a 100mm VAS (0mm=no pain, 100mm=worst imaginable pain). Participants were categorised into a PD (>10mm change from baseline value during standing) and NPD.	Lower limb and trunk kinematics. Centre of pressure was measured using a force plate. Centre of pressure shift fidget, drift frequency and amplitude and body weight shift were determined.	Thirteen participants (33%) were classified as PD. Body weight shift frequency and average shift duration decreased over time in all participants, anterior-posterior fidget amplitude increased over time. No significant effect of time for anterior-posterior shift amplitude and time spend in an asymmetrical posture were observed. PD had a greater medio-lateral fidget frequency than NPD.
10	Gallagher; 2015[31]	n=32 %female: 47% Age: NPD 22.2 (2.04) years, PD 23.0 (2.54) years Country= Canada Other specifics: Participants were selected from a university population without a history of low back pain (requiring medical care or sick leave), a standing occupation or the inability to stand for >2 hours.	Participants stood for 2 hours Relevant variables were measured every 7,5 minute	Low back pain was assessed using a 100 mm VAS with 0 being 'no pain' and 100 mm being the 'worst imaginable pain'. Participants were classified as PD if they increased their pain levels >10mm from baseline values during the standing trial.	Bilateral ground reaction force was measured with two force plates, assessing Anterior-posterior centre of pressure movement and body weight shifts. Lumbar spinal fidgets (fast and large displacement of center of pressure that returns to approximately the same location) and shifts (a fast displacement of the center of pressure from one location to another) were assessed using a motion analysis system. Also total movement (sum of shifts and fidgets) was estimated.	Fourteen participants (44%) were classified as PD. There was a significant difference between the frequency of fidgets for PD and NPD during the first 15 min (with more fidgets in NPD), but not at the 30 and 45 min time points. The number of shifts increased over time but did not differ between pain development groups. Total movements differed only during the first 15 minutes with more movement in NPD. There were no effects for center of pressure metrics.
11	Gallagher; 2016[32]	n= 17 %female: 47% Age= 22.6 (1.5) years in females and 23.3 (2.6) in males Country: Canada	Participants stood on a levelled surface for 75 minutes Relevant variables were measured every 7,5 minute.	Low back pain was assessed using a 100 mm VAS (with 0 mm being no pain and 100 mm being worst pain imaginable). Also pain in the lower limbs was assessed (gluteal pain and pain in the lower limb). Participants were classified as PD	A motion analysis system was used to assess movement of the spine (trunk, lumbar spine and hip), feet and thighs. Trunk centre of gravity and lumbar spine fidgets were assessed	Nine (53%) participants were classified as PD. Low back pain increased significantly in the PD group. There was no significant change in calf discomfort (8.6 (10.3) mm change), but discomfort in the feet increased over time (10.0 (11.3)mm change).

		Other specifics: Participants without a history of low back pain that required medical intervention or time off work were selected. Participants engaging in prolonged standing at work or with the inability to stand for two hours were excluded.		(those who changed >10mm from baseline values on the low back pain VAS) and NPD.		There was a significant but small (~2°) increase in lumbar spine flexion during standing. There were less lumbar fidgets in PD compared to NPD, which in both groups decreased over time.
12	Gregory; 2008[19]	n=16 %female: 50% Age: Males 25.1(2.1) years, females 23.5(2.3) years. Country: Canada Other specifics: Participants free of low back discomfort in the last 12 months were selected.	Participants stood for 2 hours wearing their own athletic shoes while performing precisions tasks. Relevant variables were measured every 15 minutes.	Low back discomfort was assessed using a 100mm VAS (with 0mm=no discomfort, and100mm=worst discomfort imaginable).	Muscle activity was obtained for thoracic erector spinae, lumbar erector spinae, rectus abdominis, external oblique and gluteus medius muscles, assessing the number of breaks, amplitude and number of 'shifts' in muscle activity signals. Body kinematics was obtained, assessing flexion–extension, lateral bending, axial twist angles and load (i.e., force) on the L4/L5 segment. Centre of pressure in anterior-posterior and medio-lateral direction were obtained with a force plate Muscle oxygenation was assessed using near-infrared spectroscopy. Skin temperature at the level of the thoracic and lumbar erector spinae.	Discomfort increased significantly over time and was significantly higher than baseline levels from 60 minutes onwards Variables that changed significantly over time: • Lumbar spine flexion-extension (0.35° at 15 minutes to 1.76° at 120 minutes) • L4/L5 shear force (22.6N at 15 minutes to 14.6N after 120 minutes) • Skin temperature at the level of thoracic erector spinae (31.1°C after 15 minutes to 30.7°C after 120 minutes). The development of discomfort after 2 hours could best be predicted by the following variables measured after 15 minutes • Number of centre of pressure shifts in anterior posterior direction • Number of gaps in left gluteus maximus activation • Axial twist
13	Hansen; 1998[33]	n=8 %female: 100% Age: 24(21-29) year Country: Denmark Other specifics: Participants without varicose veins were selected	Participants stood for 2 hours while performing a letter-sorting task. Standing was performed in different conditions: hard and soft surface with hard and soft shoes (data presented are overall outcomes).	Perceived discomfort in the feet, legs and low back was rated by a VAS (0%=no discomfort, 100%=worst conceivable discomfort) measured after 0, 30, 60, 115 and 120 minutes.	Volume and change in volume of the left foot was measured by hydro-plethysmography (measured before and after standing) Skin temperature of the foot was measured before and after standing Muscle activity of the bilateral erector spinae was measured, assessing RMS amplitude and mean power frequency after 5, 55 and 115	During standing, discomfort increased in the: • Low back (from 6% to 30%) • Legs (from 3% to 14%) • Feet (from 8% to 31%) Foot volume increased on average 3.9%, mainly due to a 3% increase in interstitial foot volume and a 0.9% increase in vascular volume. Foot skin temperature increased from

					minutes Movement of the centre pressure with a force plate was measured after 5, 55 and 115 minutes Oxygen uptake (VO_2), blood pressure and heart rate were measured at minute 0, 10-15, 65-70 and 100-105	32.1° to 35.5°. Centre of pressure movement increased 10-15% after 1 hour but returned to initial values after 2 hours. RMS muscle activity in the erector spinae remained the same but mean frequency increased after two hours.
14	Karimi; 2016[34]	n=10 %female: 0% Age: 25.3(1.49) years Country: Iran Other specifics: University students wearing shoe size 42 and without a job requiring prolonged standing were selected. None of the participants had lower extremity injuries/deformities, physical disabilities or discomfort.	Participants stood for 2 hours on flat-bottomed shoes[1] Relevant variables were measured every 30 minutes.	Lower leg discomfort was measured using a 100mm VAS (with 0 being 'no discomfort 'and 100 being 'worst discomfort imaginable')	Bilateral muscle activity of the gastrocnemius and tibialis anderior was measured, assessing root-mean-square and variation of the activity. Lower leg circumference was measured with a measuring tape before and after the standing protocol, estimating leg volume was estimated.	Lower leg discomfort increased over time Left and right muscle activity in both muscles increased slightly during prolonged standing. Variation of gluteus muscle activity increased gradually but that of the tibialis anterior fluctuated without an apparent increase or decrease. Leg volume increased from 991.9(76.5) to 1037.2(75.8) cm^3 in the right legs and from 996.8(87.4) to 1041.7(86.3) cm^3 in the left leg.
15	Madeleine; 1998[35]	n=10 %female: 0% Age: 23.3(0.5) years Country: Denmark Other specifics: Healthy participants were selected	Participants stood for 2 hours on a hard surface doing a simulated work task[1,2]. Relevant variables were measured every 15 minutes.	Intensity of general unpleasantness was measured on a 100mm VAS (with 0mm being not unpleasant and 100mm being most unpleasant).	Shank circumference and temperature. Muscle activity of the right soleus and tibialis anterior muscles was measured, assessing root-mean-square, mean power frequency and resting events. Also, maximal voluntary contractions pre and post standing were compared. Ankle movement in the sagittal plane was measured, assessing the mean amplitude Mean amplitude of centre of pressure displacement in the frontal and sagittal plane was assessed using a force plate	Unpleasantness increased over time (however no statistical test results were provided) Shank circumference increased 0.86(0.19)mm during the standing trial. Muscle activity, movement and displacement of the centre of pressure did not appear to change substantially over time (however no statistical test results were provided) Skin temperature increase 0.37° and 0.32° for the left and right leg, respectively.
16	Marshall; 2011[36]	n=24 %female: 67%	Participants stood in a confined area for 2 hours while completing 4 different tasks in 30 min	Low back pain was measured using a 100mm VAS pain scale (with 0=no pain, 100=worst pain imaginable)	Muscle activity of gluteus medius was measured, assessing co-activation (cross-correlation) and fatigue (median frequency),	Seventeen participants (71%) were classified PD. In this group, average change in VAS were 32(4.8), while this was only 5.9(0.9) in the NPD group.

		Age: PD 22.6(1.5) years; NPD 22.9(1.8) Country: Australia Other specifics: Participants without previous low back pain were selected	blocks Relevant variables were measured every 15 minutes	Participants were categorised in a PD (>10mm change from baseline values on the VAS) and a NPD group	Hip abduction strength and endurance and side-bridge endurance and muscle fatigue were measured pre and post standing.	Hip abduction strength was reduced by 0.36[0.32 0.94] N/kg in both groups (from 4.4(0.8) to 4.0(1.0) in PD; from 5.0(1.0) to 4.4(1.3) in NPD). Side-bridge endurance changed significantly in the PD (from 78(29.1) to 57.7(19.8)) and NPD (from 112.7(21.0) to 87.8(31.5)). Fatigue during side-bridge was higher (but not significant) after standing compared to before in the PD. This was the other way around for the NPD No changes in co-activation over time was observed.
17	Nelson-Wong; 2008[40]	N=23 %female: 48% Age: low back pain 23.9(1.8) years, no low back pain 23.9(2.3) years Country: Canada Other specifics: Participants without a history of low back pain in last 12 months were selected	Participants stood in a constrained area for 2 hours while completing 4 different tasks in 30 min blocks Relevant variables were measured every 15 minutes.	Musculoskeletal pain in various body areas (neck, shoulder, upper back and low back) was assessed on a 100mm VAS with 0="no pain" and 100="worst pain imaginable"). Only low back pain was used in (as it showed the most consistent increase). Participants were categorised into a PD (>20mm at any point and >10mm overall average VAS score) and a NPD group	Muscle activity of bilateral lumbar erector spinae, thoracic erector spinae, rectus abdominus, external oblique and gluteus medius were measured, assessing co-contraction (cross-correlation between muscles).	Fifteen participants (65%) were considered PD. There were effects of time ($p<0.001$), group ($p<0.001$) and interaction between group and time ($p<0.001$) for low back pain There were no significant difference between PD and NPD for co-actiation between thoracic erector spinae and rectus abdominus, or external obliques, bilateral thoracic erector spinae, lumbar erector spinae and rectus abdominus, or bilateral lumbar erector spinae muscles. There were significant differences for co-activation of bilateral gluteus medius and lumbar erector spinae with external oblique muscles
18	Nelson-Wong; 2010A[37]	n=41 %female: 49% Age: low back pain 23.5(3.7) years, no low back pain 22.1 (3.0) years Country: Canada Other specifics: Participants without lifetime event of low back pain	Participants stood for 2 hours performing 3 different 30 min simulated occupational tasks[3] Relevant variables were measured every 15 minutes.	Low back pain was assessed on a 100mm VAS (with 0 being "no pain" and 100 being "worst pain imaginable") Participants were categorised into a PD (>10mm increase from baseline values in VAS score) and a NPD group	-	Seventeen participants (41%) were classified PD

		requiring management of healthcare practitioner or 3 days off work or current low back/hip pain were selected				
19	Nelson-Wong; 2010B[39]	n=43 %female: 49% Age: low back pain 23.5(3.7) years, no low back pain 22.1(3.0) years Country: Canada Other specifics: Participants without lifetime event of low back pain requiring management of healthcare practitioner or 3 days off work or current low back/hip pain were selected	Participants stood for 2 hours performing 3 different 30 min simulated occupational tasks Relevant variables were measured every 15 minutes.	Low back pain was assessed on a 100mm VAS (with 0 being "no pain" and 100 being "worst pain imaginable") Participants were categorised into a PD (>10mm increase from baseline in VAS score) and a NPD group	Muscle activity from bilateral lumbar erector spinae, thoracic erector spinae, latissimus dorsi, rectus abdominus, internal oblique external oblique and gluteus medius and gluteus maximus were measured, assessing co-contraction (cross-correlation) between muscles.	Twenty participants (46%) were considered PD. There was a significant interaction between group and time ($p< 0.001$) for low back pain PDs demonstrated bilateral gluteus medius and trunk flexor–extensor muscle co-activation prior to reports of PD. PD and NPD demonstrated markedly different patterns of muscle activation during standing
20	Nelson-Wong; 2010C[38]	n=23 %female: 48% Age:. NPD 22.6(3.3) years, NPD 22.1(2.9) years Country: Canada Other specifics: Participants without any significant lifetime events of low back pain or with the ability to stand for >4 hours were selected.	During two measurement days (4 weeks apart), participants stood for 2 hours. Relevant variables were measured every 15 minutes.	Low back pain was assessed using a 100mm VAS (with 0 being no pain and 100 being the worst pain imaginable) Participants were classified PD (when changing >10mm from baseline on the VAS) or NPD	[4]	Eight participants (35%) were classified PD at the first measurement occasion, while 6 of them would still be classified PD during the second measurement. Fifteen participants were classified NPD on the first measurement occasion, while 13 remained NPD after the second measurement occasion
21	Raftry; 2012[41]	n=20 %female: 66% Age: 22.6(2.7) years Country: Australia Other specifics: Young adults without a lifetime history of low back pain were selected	2 hours standing protocol in a confined space performing various tasks.	Low back pain was assessed using a 100mm VAS scale (with 0 being 'no pain' and 100 being 'worst pain'). Participants were categorised in a PD (>10mm change from baseline in VAS) and a NPD group.	Hamstring stiffness (maximum torque required to raise the leg) and extensibility (maximum extension angle) was measured with a dynamometer Stretch tolerance during the testing protocol was measured with a VAS (no-pain=0mm; worst pain=100mm)	Ten participants (50%) were considered PD. Change in VAS was 36.4(21.9) in the PD group and 2.9(0.9) in the NPD group No differences in hamstring stiffness, extensibility or hamstring stretch tolerance between the two group or changes over time were observed.
22	Seo; 1996[46]	n=12 %females: 33%	Participants stood for one hour in a confined space (in which participants	Leg dullness, low back pain and whole body fatigue were self-reported on a 10 level scale	Swelling of the lower leg was measured using electrode impedance.	The three subjective scores increased over time

		Age: 24.1(1.2) years; Country: Japan Other specifics: Participants not suffering from oedematous disease, varicose veins or injury in the lower leg were selected	were permitted to walk). Relevant variables were measured every 2 minutes.	(1=lowest, 10=highest)		There was a 5.9(4.1)% increase in leg swelling after 30 minutes and a 5.9(3.7)% increase after 60 minutes.
23	Sorensen; 2015A[43]	n= 57 %female: 49% Age: NPD 23.9(3.5) years, PD 24.7(3.3) years Country: USA Other: Health volunteers with no lifetime history of an episode of low back pain requiring health intervention, ≥ 3 consecutive days of missed work or school or ≥3 days altered activities of daily living were selected.	Participants stood for 2 hours.	Low back pain was measure with a 100mm VAS (with 0m being 'no pain' and 100mm being worst pain imaginable) every 15 minutes. Participants were classified as PD (reported any symptoms after baseline) and NPD.	At baseline, body posture of the trunk (using motion analysis system) were measured, assessing lumbar curvature was estimated.	Twenty-four participants (42%) were classified as PD. PDs displayed a significantly larger lumbar curvature (4.4° difference) and in PD, lumbar curvature was significantly associated with the maximum pain score.
24	Sorensen; 2015B[42]	n=53 healthy participants and n=15 participants with low back pain %female: NBP 60%, PD 60% Age: NPD 23.5(3.1) years, PD 22.7(1.6) years Country: USA Other specifics: People with low back pain (any lifetime episode of pain resulting in >3 days of missed work or school or seeking health interventions) and healthy controls were selected. Participants unable to stand >4 hours and those with high BMI were excluded.	Participants stood for 2 hours Relevant variables were measured every 15 minutes.	Low back pain was measure with a 100mm VAS (with 0 being no pain and 100mm being the worst pain imaginable). Healthy participants were classified as PD (those who changed ≥10 mm on the pain scale) and NPD.	-	Fifteen of the healthy participants (28%) were categorised as PD. There was a 18.7 [13.6 23.9] difference in change in pain score between PD and NPD during the standing trial.
25	Stewart; 2016[44]	n= 16 %female: 50%	Participants stood for 2 hours Relevant variables were	A perceived pain scale was used to assess low back pain with a VAS from 0 (no pain) to 100 (worst pain imaginable).	-	Low back pain increased significantly during the two hours of standing. Eight participants (50%) were considered PD.

		Age: Males 22.75(0.92) years, females 22.88(0.93) years Country: Canada Other specifics: University students were selected. Participants with chronic low back pain in the past 12 months were excluded.	measured every 15 minutes[1].	Participants who ranked their low back pain ≥8mm were classified as PD.		Averaged over the two hours of standing, low back pain for NPD was 1.64 mm (SE 0.4) and 16.19 mm (SE 1.78) for PD. Low back pain at the end of the standing protocol for NPD was 2.75 mm (SE 1.6) and 28.33 mm (SE 5.49) for PD.
26	Zhang; 1991[47]	n=6 %female: 17% Age: range 24-45 years Country: USA Other specifics: Healthy participants were selected	Participants stood for two hours. Relevant variables were measured every 15 minutes.	Discomfort was measured with using a 10 point scale (with 0=nothing at all and 10=almost maximal). Three variables were reported on: 1. Number of body parts with discomfort >1 2. Mean discomfort for all non-zero discomfort scores 'sum of discomfort severity' 3. Sum of discomfort severity	Muscle activity of tibialis anterior and gastrocnemius were measured Centre of gravity was obtained with a force plate (with standard deviation in sagittal, lateral and combined direction as well as distance of the centre of gravity) Video recordings were performed and number of posture changes were counted.	Foot and lower leg discomfort were the most frequently reported discomfort sited. There were significant effects of time for most of the measured variables (discomfort scores, centre of gravity, posture changes), but not the muscle activity.
PD = Pain developers NPD = Non-pain developers						