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Dynamic standing as an effective and feasible strategy to combat the health risks of prolonged sitting and static standing

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Dynamic standing as an effective and feasible strategy to combat the health risks of prolonged sitting and static standing

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1. Introduction

Prolonged sitting has been identified as a risk factor for acute metabolic disorders, such as glucose intolerance and adverse peripheral hemodynamic changes. Standing which breaks up the prolonged sitting periods has been proposed as a strategy to combat these adverse health outcomes. However, prolonged static standing is not without harms. A relatively strong evidence base from ergonomic literature opposes the promotion of prolonged static standing as healthy posture. Instead, standing should be frequently broken up with sitting or movement.

Another, potentially healthier alternative for static standing, is dynamic standing. Dynamic standing can refer to ambulating legs while standing. This ambulation can be assisted with ergonomic products, such as balance boards. The purpose of this report is to give an overview on the biomechanical and metabolic mechanisms that support the use of dynamic standing, instead of static standing, to combat the health risks of sitting. Moreover, we give an overview on randomized controlled trials using dynamic standing to improve metabolic and musculoskeletal health, as well as productivity outcomes. These results are relevant for occupational settings where prolonged sitting, as well as prolonged static standing, introduce a health risk for employees.

2. Health effects of sitting

2.1 Metabolic health risks of prolonged sitting

It is important to differentiate between sedentary behaviour and physical inactivity. Physical inactivity is defined as not meeting the current guidelines for health-enhancing physical activity, i.e. not exercising enough. While, *sedentary behaviour* is defined as any waking activity performed in a sitting/lying position expending very little energy (about 1.0–1.5 METs) (Sedentary Behaviour Research Network 2012, Tremblay et al. 2017). Therefore, both sedentary behaviour and physical activity can coexist.

There is increasing amount of research on identifying health risks associated with sedentary behaviours. The dose-response relationship between sitting time and mortality rates has been found to be comparable among those who are physically inactive and active, and across body mass index categories (Katzmarzyk, Gledhill & Shephard 2000). Indeed, epidemiological studies have shown that sedentary time predicts metabolic syndrome (Dunstan et al. 2005, Bertrais et al. 2005), abnormal glucose metabolism (Dunstan et al. 2004 and 2007), obesity (Hu 2003, Jakes et al. 2003), type II diabetes (Hu 2003, Hu et al. 2001), high blood pressure (Jakes et al. 2003), cardiovascular disease (Kronenberg et al. 2000) and all-cause mortality (Katzmarzyk et al. 2009) independently from exercise.

In addition to total sedentary time, the pattern of the accumulation of sedentary time seems to be also important in relation to its negative health consequences. It has been shown that the total number of breaks (e.g. on average of light intensity and lasting less than 5 minutes) in sedentary time is associated with significantly lower waist circumference, BMI, 2-h plasma glucose and triglycerides independent of total sedentary time (Healy et al. 2008). Based on these results, it has been suggested that breaking prolonged periods of sitting could be a valuable addition to the physical activity recommendations (Healy et al. 2008).

2.2 Effectiveness of breaking up prolonged sitting with physical activity

Studies using compositional and isotemporal data analysis methods have found that when replacing sedentary behaviour with physical activity, the magnitude of sedentary behaviour-related risk is decreased. In a group of healthy participants, a statistical replacement of 10 minutes of sedentary time with moderate-to-vigorous physical activity, but not with light activity, showed beneficial associations to cardio-metabolic health markers (Hamer et al. 2014).

In another study utilizing similar analysis methods, reallocating 30 minutes of sedentary time to light activity was beneficially associated with cardio-metabolic health markers (Buman et al. 2014). Yet, reallocating same amount of sedentary time to moderate-to-vigorous activity was associated with more sizeable benefits. A study by Wellburn et al. (2016) showed that 50 minutes of light activity is required to produce similar benefits to 10 minutes of moderate-to-vigorous activity (Wellburn et al. 2016). Therefore, when the intensity of replacement activity is higher, the benefits of reallocating sedentary time to activity are larger or can be gained in a shorter period of time.

The pattern in which sedentary time is accumulated might also be important regardless of the total sedentary time. Healy et al. (2008) showed that breaks in sedentary time were beneficially associated with BMI, waist circumference, triglycerides and 2-h plasma glucose independent of total sedentary time and moderate-to-vigorous physical activity (Healy et al. 2008).

As reviewed recently, cross-sectional findings support the association of breaks in sedentary time on obesity metrics (Chastin et al. 2015; Brocklebank et al. 2015) and on triglycerides independent of moderate-to-vigorous activity or total sedentary time. Based on these findings, it appears as each part of the sedentary behavior pattern, namely frequency, interruptions, time and type of sedentary behavior, to have its own unique influence on health outcomes.

"…each part of the sedentary behavior pattern, namely frequency, interruptions, time and type of sedentary behavior, to have its own unique influence on health outcomes."

3. Health effects of standing

3.1 Static and dynamic standing

Static and dynamic standing should be considered as different activity types as loading and muscle activation patterns differ considerably between them. In occupational setting dynamic standing has been defined as ergonomic posture, in which a worker intermittently walks while he is on the job (Balasubramanian et al. 2009). In a broader sense dynamic standing can be defined as standing posture, in which person is doing some movements (for example fidgeting or balancing on a soft or unstable surface).

"… dynamic standing can be defined as standing posture, in which person is doing some movements (for example fidgeting or balancing on a soft or unstable surface)."

Its stationary equivalent, passive or stationary standing is a posture, in which an individual does not walk or move, but stands rather still. It has been reported that stationary standing accelerates the onset of fatigue, decreases the blood flow to the muscles, and causes pain in the leg, back and neck muscles (Quiros, 2001). High incidences of low-back pain have been associated with prolonged static standing over 4 hours per day (Jorgensen, Hansen, Lundager, & Winkel, 1993; Magora, 1972). Furthermore, daily working for prolonged periods in a stationary standing has been linked to aggravated muscle fatigue, lower back pain, stiffness in the neck/shoulders, and other health problems (Dempsey, 1998).

In his study with industrial workers, Balasubramanian et al. (2009) found that dynamic standing posture fatigues lower extremity muscles at a much slower rate than a stationary standing posture. Furthermore, the perceived pain/discomfort in the muscles is also lower during a dynamic compared to a stationary posture (Balasubramanian et al. 2009). Due to these findings dynamic standing should be preferred choice over stationary standing.

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Especially, in industrial work that cannot be performed sitting down such an ergonomic design reduces the risk of acquiring musculoskeletal disorders among laborers and may have a positive impact on productivity enhancement (Balasubramanian et al. 2009).

3.2 Ergonomics of standing

Epidemiological studies suggest that prolonged standing may be associated with adverse health issues such as atherosclerotic progression, venous insufficiency, as well as back and lower limb discomfort (Baker et al. 2018). Baker et al. (2018) found that prolonged bouts of standing (up to two hours of uninterrupted standing) resulted in increased discomfort in multiple areas of the body and decreases in cognition.

Also, epidemiological studies of occupations that require prolonged standing (e.g. workers in industrial and retail) have found several negative health issues associated with too much standing including chronic venous insufficiency and varicose veins (Beebe-Dimmer *et al.* 2005, Tuchsen *et al.* 2005), perinatal risks (Mozurkewich *et al.* 2000, Magann *et al.* 2005), atherosclerotic progression (Krause *et al.* 2000), and symptoms in the back (Coenen *et al.* 2016) and lower limbs (Leroux *et al.* 2005). Although, it has been suggested that less constrained posture in standing compared to sitting allows more movement. Consequently, movement reduces static muscle contractions and potentially work-related discomfort (Roelofs and Straker 2002). These studies do not explicitly define whether standing was static or dynamic and this should be considered when interpreting the findings of these studies.

3.3 Discomfort and productivity

Perceived mental state has been found to deteriorate with prolonged static standing and to be moderately correlated with body discomfort (Baker et al. 2018). This finding is in line findings of Hasegawa et al. (2001) who observed increased signs of fatigue (such as changing position, stretching, yawning) in standing compared to sitting and Chester et al. (2002) who reported a trend for tiredness to increase with time. To avoid mental state deterioration, probably movement is required, and this may also assist with managing discomfort (Baker et al. 2018). Movement could be incorporated, for example, through dynamic standing or intermittent activity breaks that would break the monotony of static standing.

"To avoid mental state deterioration, probably lower or higher level of movement is required, and this may also assist with managing discomfort."

In ergonomics it is important to distinguish between static and dynamic work of the muscles. Dynamic work is characterized by a rhythmic change of relaxation and contraction of the muscles, which is a favourable condition for the blood supply of the working muscles. Static work, in contrast, is characterized by slow contractions or by extended, lasting holding postures. In forceful static muscle contraction, the blood supply is impaired and waste products start to accumulate in the muscles, that causes the acute pain in the statically loaded muscle. If the static load is repeated either for long periods of time and frequently enough, chronic pains and conditions may result. Commonly, these pains are not only related to pathological changes in the muscles, but also in the connective tissues of the ligaments, tendons, and joint capsules. (Grandjean & Hunting 1977)

3.4 Blood flow and swelling of legs during standing and walking

During prolonged stationary standing metabolic wastes tend to accumulate within the muscles because of the reduced blood flow (Balasubramanian et al. 2009). The stillness of legs in such a case can lead to an accumulation of the blood in the lower legs, which can, in turn, cause leg swelling and edema.

In dynamic standing, phasic muscle contractions are likely to assist with venous return and reduce swelling of the legs (Baker et al. 2018). Studies have indeed found that unrestricted standing results in less swelling than sitting despite the higher hydrostatic pressure during standing (Seo et al. 1996). Dynamic standing has potential to increase productivity (Balasubramanian et al. 2009) as perceived mental state has been found to be moderately correlated with body discomfort (Baker et al. 2018).

"Dynamic standing has the potential to increase productivity…"

The mean venous pressure in the ankle during standing is between 80 and 87 mm (Chester et al., 2002; Konz and Johnson, 2000) and interestingly walking drops the ankle venous pressure down to a baseline value of 21 to 23 mm in just 10 steps (Konz and Johnson, 2000). Due to these findings, it has been suggesting performing 2–4 min of walking or movement for every 15 min of stationary standing work (Konz and Johnson 2000).

"Therefore, even short duration of movement during standing has beneficial effects."

3.5 Pressure on the feet during standing

Discomfort experienced in the feet is somewhat related to pressure under the feet. During standing, the weight-transmitting area of the foot (ball of great toe and heel) is compressed and deformed by the pressure (Balasubramanian 2008). This can inhibit the supply of blood to the area, resulting in oxygen deficiency of the tissue, and can cause discomfort and fatigue (Henderson, Price, Brandstater, & Mandac, 1994). Due to this, softer surfaces and movement can help in the discomfort and fatigue experienced during standing by redistributing the pressure to different areas of the feet. It is postulated that unloading of passive tissues through movement is used to alleviate or manage discomfort (Gallagher and Callaghan 2015) however further research is required to investigate whether the movement is pre-emptive or reactionary. Despite exact scientific proof, it is rather straightforward to assume that movement during dynamic standing would change the pressure distribution under the feet and that way help reduce the discomfort caused by pressure on weigh-transmitting areas of the feet.

4. Incorrect posture and musculoskeletal problems

4.1 Health problems related to poor posture

Many of the aches, pains and musculoskeletal problems of adults are the result of the long-term effects of incorrect postures or body misalignment. For example, postural kyphosis (excessive rounding of the upper spine) in adolescence may be a result of poor sitting and standing habits. Scientific studies have linked poor posture to several health problems and concerns, including back pain, neck pain, spinal stress, reduced lung capacity, joint and muscle injury, headaches, fatigue, high blood pressure, stroke, higher susceptibility to injury, and even dental problems and diabetes.

Furthermore, multiple studies have found an association between poor work posture and back pain (e.g. Nowotny et al. 2011, Wong et al. 2009, and Tissot et al. 2009). Studies have shown that prolonged static trunk flexion can subject the spine to reduced muscle activity of multifidus (Williams et al. 2000), provoke flexion relaxation phenomenon of the thoracic erector spinae (resulting in the creep response of the tissues of lumbar spine) (e.g. McGill & Brown 1992), reduce the oxygenation of lumbar extensors due to the constant isometric contraction (McGill et al. 2000), and increase the intradiscal pressure (Wilke et al 1999). The effects of incorrect posture also include disturbances of the symmetric distribution of tensile and compressive forces acting on both sides of the body and the emergence of harmful shear forces. Additionally, the torques of antigravity muscles also change unfavourably. This may lead to the development of a repetitive strain syndrome, compression of nerve roots, stenosis of intervertebral foramina, and back pain (Nowotny et al. 2011) therefore highlighting the importance to avoid poor work postures and have enough variation in postures and tasks throughout the day.

4.2 Task variation

Task variation in repetitive work has been an area of interest as it can possibly alleviate fatigue and the risks of musculoskeletal disorders. Task variation includes changes in task characteristics, postural changes, and breaks. Especially important are breaks that include an exercise regime, or a change in posture from that used when working. Even though there is rather little high-quality scientific evidence about positive effects of variation in postures, there is general agreement among clinicians and researchers that variation is better than static postures that are held in extended periods of time. Increased variability between job tasks of an individual can be achieved by introducing new tasks that vary in the movements and postures required (Moller et al., 2001, HSE, 2002, Canadian centre for occupational health and safety, Brown & Mitchell, 1988, Ergo in demand, Occupational safety and health, 1991 and the Swedish work environment authority, 2005). Similarly, performing exercises can be considered as a way of providing a variation of movement and posture. Exercise breaks or conventional rest breaks provide a way of increasing 'variation' in the job without requiring work tasks to be reallocated among workers. Therefore, different kind of breaks provide a practical way to decrease the risk of musculoskeletal disorders and is one of the most frequently recommended interventions against musculoskeletal disorders (Konz 1998).

"There is general agreement among clinicians and researchers that variation is better than static postures that are held in extended periods of time."

4.3 Adverse effects of static postures and sitting on intervertebral discs

The type of posture is not only important to static muscle strain and muscle fatigue, it is even more important for a healthy spine and more specifically to healthy interverbal discs (Grandjean & Hunting 1977). In industry, backache is the most frequent cause of absenteeism and the main reason for these backaches is a degeneration of the interverbal discs. The degeneration of the discs is accompanied by a flattening of the discs, and by a loss of mechanical resistance leading to nerve irritations, to mechanical troubles between the vertebrae, and to pains.

Pressure inside the discs is considerably higher when the trunk is bent forwards compared with standing in an upright position (Nachemson and Elfstrtim 1970; Andersson and Ortengren 1974; Nachemson 1974). Furthermore, the intradiscal pressure is higher in the sitting than in the standing posture. This is very likely due to the turning mechanism of the hips in the sitting position, which results in a kyphosis in the lumbar region of the spine. Considerable increase in intradiscal pressure should be considered as an unnecessary load and strain on the discs, promoting pathological changes.

4.4 Movement of interverbal discs

It is well known that the interverbal discs themselves do not have a good blood supply (Grandjean & Hünting 1977) and it has been shown that nutritive substances are transported by diffusion with tissue liquids into the disc (Krämer 1973). If the load on the disc is heavy, the tissue liquids flow out of the disc, and in turn, if the load is small, the tissue liquid flows into the disc. It has been concluded that a periodical change of the load on the discs provides an effective pump mechanism and is important for their nutrition and thus also for their resistance against pathological changes (Krämer 1973; Grandjean & Hünting 1977). This evidence supports the notion that movement during dynamic standing provides an effective way to facilitate the transport of nutritive substances to the interverbal discs of the spine and thus protect discs against pathological changes.

"…dynamic standing provides an effective way to facilitate the transport of nutritive substances to the interverbal discs of the spine and protect discs against pathological changes."

5. Recommendations for active working

In predominantly desk-based occupations, workers should aim to follow these recommendations (Buckley et al. 2015):

- Initially progress towards accumulating at least 2 h/day of standing and light activity during working hours, eventually progressing to a total of 4 h/day (prorated to part-time hours).

- Sitting should be regularly broken up with standing and vice versa, and thus, sit–stand adjustable desk stations are highly recommended.

- Prolonged static standing postures should be avoided; movement needs to be checked and corrected on a regular basis especially in the presence of any musculoskeletal sensations.

6. Balance training

Dynamic standing on an unbalanced surface can be considered as balance training. In general balance, or postural control is considered to be a critical component of motor skills as poor balance is associated with injury or falls in many populations

(Burke et al. 2008; Gabbard 2008; McGuine et al. 2000). Balance is defined as the ability to maintain the centre of gravity of the body within its base of support and can be categorized into static or dynamic balance. Static balance is the ability to maintain the body in static equilibrium (Goldie et al. 1989; Olmsted et al. 2002). Dynamic balance is more challenging as it requires the ability to sustain equilibrium during a transition from a dynamic to a static state (Ross & Guskiewicz 2004). Balance requires effective integration of vestibular, proprioceptive and visual inputs to produce an efferent response to control the body within its base of support (Guskiewicz & Perrin 1996; Irrgang et al. 1994). Loss of balance can result in injury. Especially, poor balance has been linked to lateral ankle sprains (McGuine et al. 2000) and can explain differences between individuals with and without functional ankle instability (Ross & Guskiewicz 2004 and 2005; Wikstrom et al. 2007). Therefore, improving balance is an important objective of many rehabilitation and injury prevention programs (Emery et al. 2005, Junge et al. 2002; Myklebust et al. 2003, Olsen et al. 2005; Wedderkopp et al. 1999).

"…improving balance is an important objective of many rehabilitation and injury prevention programs."

Systematic scientific review provides strong evidence that both static and dynamic balance can be improved by training. 14 out of 16 well-performed scientific articles demonstrated balance improvements after their training program (DiStefano et al. 2009). The 2 studies that did not observe balance improvements assessed static balance, which may be an outcome that is too easy for healthy subjects to show improvement (Cox et al. 1993; Puls & Gribble 2007).

There has been speculation that perhaps balance improvements are not possible with a functional and healthy people. The results of above-mentioned studies do not support this speculation as all the studies had a healthy population and the majority found dramatic improvements in balance. Two of the studies had even elite athletes as participants and still observed improvements (Holm et al. 2004; Kovacs et al. 2004). Therefore, balance training is beneficial also for healthy normal people and even to skilful elite athletes.

"…balance training is beneficial also for healthy normal people and even to skilful elite athletes."

Balance training performed at least 10 minutes per day, 3 days per week, for 4 weeks balance training appear to improve balance ability. Types of balance training can include the use of unstable surfaces, tilt boards, and dynamic body movements while maintaining a static stance.

7. Summary and conclusions

Following main points can be stated related to different aspects of sitting and sedentary behaviour, task variation and breaks, and static and dynamic standing:

Sitting and sedentary behaviour:

- **Sedentary time predicts several chronic health conditions** independently from exercise.

- **Breaks in sedentary time are associated with several health benefits** independent of total sedentary time and moderate-to-vigorous physical activity

Task variation and breaks:

- Different kind of **activity breaks** provide a practical way to **decrease the risk of musculoskeletal disorders**.

- There is general agreement among clinicians and researchers that **variation is better than extended static postures**.

Static and dynamic standing:

- **Prolonged static** standing may be associated with **discomfort** in multiple areas of the body, **decreases in cognition**, and **adverse health issues.**
- **Perceived mental** state has been found to **deteriorate with prolonged static standing** and this can probably be avoided with lower or higher level of movement.
- **During prolonged stationary** standing **metabolic wastes accumulate** within the muscles and can lead to **leg swelling and edema**.
- Movement during dynamic standing seems to **protect intervertebral discs against pathological changes**.
- **Dynamic standing** with rhythmic change of relaxation and contraction of the muscles is a **favourable condition for the blood supply** of the working muscles and **venous return**.
- Dynamic standing on unbalanced surface can be considered as **balance training**, which has been shown to be **beneficial also for healthy working age people**
- **Dynamic standing** has potential to **increase productivity** as it decreases body discomfort related to static standing.

In conclusion, sitting, static standing and static postures in general are related to adverse health outcomes ranging from body discomfort to musculoskeletal problems and to variety of chronic diseases. These adverse health effects can be mitigated by introducing activity breaks, replacing static standing with dynamic standing and by providing variation to extended static postures.

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