Analysis of the Effects of the Prolonged Standing and Sitting Posture on Physiological Indicators, and the Potential Impact on Health: A Systematic Review and Meta-Analysis

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Prolonged standing and sitting in the job environment are one of the principal causes of cardiovascular disease and musculoskeletal disorders. However, these diseases turn out to be just the results of sedentary postures and little has been analyzed regarding physiological indicators due to extended workdays. The main objective of this study was to do a systematic review and a meta-analysis using PRISMA strategy on the effects of prolonged standing and sitting postures in physiological biomarkers measured in work tasks, simulated workday activities and uninterrupted postures evaluated in laboratory. This study is intended to analyze different effects of prolonged standing and sitting in physiological indicators and its possible impact on human health due to these postures. A total of 46 studies for the seated posture and 29 for the standing posture were selected and included in the 95% IC meta-analysis. Results have proven statistical significance and reliable heterogeneity for the following biomarkers: Amplitude muscle twitch force indicator MTF (p=<0.001; I^2=0%), Mean arterial pressure (p=0.049; I^2=15.09%), Venous refilling time (<0.001; 43.86%), Lower limb volume (p=<0.001; I^2=0%) for prolonged standing in healthy population and Lower leg circumference (p=0.031; I^2=0%), Triglycerides (p=0.007; I^2=15.57%) for prolonged sitting posture in healthy and overweight population respectively.

Keywords
Prolonged standing and sitting, physiological biomarkers, cardiometabolic outcomes, vascular outcomes and sedentary lifestyle.

1. Introduction
One of the most common ergonomic risk factors in the industry is staying in the same posture for long periods of time; these includes prolonged standing and sitting. In this context, it is known that between 60 – 70% of the European labor force spend more than 75% of their work shift in prolonged standing (Parent-Thirion et al. 2012). In the case of the United States, workers tend to spend between 50 – 70% of their day in one posture (Matthews et al. 2008). Office workers are exposed to 65% of their shift in prolonged sitting, which shows how common sedentary jobs are today (Clemes et al. 2014). The nature of sedentary work tasks corresponds to 43% of all jobs and is mostly found in the service industry (Brierley et al. 2019).

Research in this area has focused on physiological biomarkers to evaluate prolonged sedentary sitting and reclining postures impact on the human body (Hwang et al. 2021). These prolonged sedentary postures, are mostly characterized as any activity with low energy expenditure lower than 1.5 metabolic equivalents METs (Young et al. 2016). Physiological biomarkers have been considered as main cause mechanisms to cardiovascular problems (Jan de

Kok et al. 2019; Hulst 2003) and musculoskeletal disorders (MSDs) (Valachi and Valachi 2003). Among the main cardiovascular diseases, cardiorespiratory impact tends to be quite evident as Kulinski et al. (2014) reported a decrease in the metabolic equivalent of 0.12 and 0.24 for men and women respectively, who are currently exposed to a prolonged sedentary activity combined between sitting and standing, plus it has been associated to an increase in cardiovascular mortality. On the contrary, the results of the METs for physical activity behavior were reported as an increase of 0.88 and 1.37 for men and women respectively (Kulinski et al. 2014). Another negative cardiovascular association is the job strain which has its effects in physiological biomarkers related to job stress. Schnall et al. (1998) analyzed a service industry population that spend most of their day in a sedentary posture combined between sitting and standing according to different work sites. The study supported that there was an increase in the mean arterial pressure and thus possible levels of hypertension. Regarding MSDs, research supports that being exposed to prolonged postures mostly sitting, affects notoriously joints mobility, nerves compression and spine vertebral disks (Valachi and Valachi 2003).

1.1 Objectives

Having explained this context, the main objective of this study is to do a systematic review and meta-analysis of published literature, to evaluate the different effects of prolonged standing and sitting in physiological biomarkers at the work environment. It is intended to contribute to literature with a revision that could serve as a guide to possible studies focused on the impact of prolonged standing and sitting. This study analyzes to what extent prolonged standing and sitting postures affect physiological biomarkers.

2. Literature Review

As it is evidenced, sedentarism is entailed by prolonged postures in standing and sitting. As for prolonged sitting, the most common jobs are technology specialists, office workers, drivers, seamstresses, who are exposed more than 2 hours daily (Łastowiecka-Moras 2020). Common health incidences in this posture have been related to diabetes type 2 (Dempsey et al. 2017), lung cancer (Jiang et al. 2019), hypertension (Mackie et al. 2019), obesity and high mortality (Flegal et al. 2005). Additionally, there is a natural relation between prolonged seated jobs and an increase in MSDs and cardiovascular problems, which have had a rapid increase since 2010 (Jan de Kok et al. 2019). Being exposed to prolonged sitting, affects considerably upper and lower limbs muscles on account that during the exposure time they are not used in normal range motion and therefore causes cellular processes variations and energy expenditure (Hamilton et al. 2007).

With respect to physiological biomarkers in this posture, Singh et al. (2017) and Vena et al. (2016) analyzed leg fluid volume. By the same token, Restaino et al. (2015) and Brien et al. (2021), measured lower leg circumference; both indicators have been related to lower limbs swelling. On the other hand, Zeigler et al. (2016), Wennberg et al. (2016) and Kruse et al. (2018), contributed to the understanding of cardiovascular indicators like the blood pressure.

Prolonged standing, on the other hand, has had a high incidence in the manufacturing industry and medical services (Ngomo et al. 2008). The most common jobs are teachers, shopping assistants, chefs, pharmaceutics, who are currently exposed to uninterrupted standing (Łastowiecka-Moras 2020). Common illnesses are vascular problems (Sudoł-Szopińska et al. 2011), plantar fasciitis (Vaamonde-Lorenzo et al. 2019), chronic venous insufficiency (Tüchsen et al. 2016), lower limb swelling (Kim et al. 2021) and MSDs effects in lower and upper back and neck (Alias et al. 2020; Mohseni Bandpei et al. 2014).

Common physiological biomarkers of this posture could be evidenced in several studies (Blättler et al. 2016; Gianesini et al. 2020; Kim et al. 2021; Zander et al. 2004) these include vascular indicators measures; (Wall et al. 2020; Garcia et al. 2015; Garcia et al. 2016; Garcia et al. 2018) for muscular fatigue of the lower leg and lower leg edema (Lin et al. 2012a; Lin et al. 2012b; Kim et al. 2021). Back measures and its effects in pain development has also been analyzed regarding postural changes like lumbar lordosis and lower limb muscle activation (Sorensen et al. 2015; Gallagher et al. 2011; Lafond et al. 2009; Nelson-Wong and Callaghan 2010; Marshall et al. 2011; J. Y. Lee et al. 2018)

Published literature has analyzed how physiological biomarkers change over time during standing and or sitting work as well as analysis for ergonomic interventions such as the use of dynamic workstations (Dupont et al. 2019); active bouts of physical activity during work shift (Henson et al. 2016) and change in clothing during working hours (Karimi et al. 2016), among others. However, to our knowledge, a systematic review with meta–analysis that integrates the

effects of prolonged standing or sitting in physiological biomarkers does not exist. Most of published systematic reviews with meta–analysis in this context have an epidemiologic focus and do not summarize the effect of both postures. For instance, Paterson et al. (2020) studied exposure to prolonged sitting on vascular dysfunction in lower limbs arteries, which is linked with getting possible cardiovascular diseases. On the other hand, Coenen et al. (2018) analyzed prolonged occupational standing and the detrimental associations with musculoskeletal symptoms and concluded on the occurrence of low back symptoms. This clearly indicates the main concern on the resultant disease than the changing in physiological biomarkers influenced by prolonged posture, which is the main concern of the present study.

Some articles analyze more biomarkers than others, thus presenting more robust conclusions. For instance, when studying metabolic indicators due to prolonged sitting, Dunning et al. (2018) studied 6 variables (insulin, glucose, cholesterol, high and low density lipoproteins and triglycerides) while Miyashita et al. (2013) considered just 2 variables (insulin and glucose). A similar thing was evidenced in leg swelling measures for prolonged standing, where Kim et al. (2021) analyzed 7 variables (leg volume, leg circumference for 5 zones and leg extracellular fluid) while Lin et al. (2012) considered 2 variables to be enough (thigh and shank circumference). This generates a gap in the analysis of physiological biomarkers. Additionally, there are different measures processes that depend on and differ among the equipment and techniques used which clearly limits a project extent. For example, in Paterson et al. (2020) study, they managed to conclude on vascular dysfunction in lower limbs arteries only with the flow mediated dilation (%FMD) and neglected other biomarkers related to MSDs. Given this gap of physiological biomarkers analyzed separately by different studies in published literature, it is intended to gather physiological biomarkers measures that could possibly show and increase or decrease due to prolonged standing and sitting posture.

3. Methods

The methodology used for this study was PRISMA, which is a methodology used for systematic reviews and meta-analysis. This methodology is based on a quality research that ensures the integrity of the systematic review and meta-analysis (Liberati et al. 2009).

3.1 Inclusion and Exclusion criteria

Studies were selected if they satisfied the following: if studies were in English, studies that analyzed effects of prolonged standing or sitting exposures in all kind of physiological biomarkers, sitting studies with the years (2010-2021) and standing studies with years (1986-2021), studies that reported pre and post exposure measures with central tendency and dispersion metrics, studies that analyzed a population older than 16 and younger than 75 years old with all kind of health status and sample, studies that reported the physiological biomarkers influenced by work activities, or simulated work activities in laboratory settings.

Studies were excluded if they satisfied the following: if studies did not report the pre and post exposure results, if in the studies that analyzed external interventions apart from posture, such as dynamic workstations, bouts of physical activity, was not evidenced the physiological biomarkers change on the control group that was only exposed to prolonged posture exposure, studies that did not show central tendency and dispersion measures.

3.2 Research databases

The primary databases selected were ScienceDirect – Elsevier, PubMed, Scopus and the complimentary databases were Google Scholar and Springer. The research strategy was: (prolonged standing OR prolonged sitting OR uninterrupted standing OR uninterrupted sitting) AND (physiology) AND (physiological outcomes OR physiological variables OR physiological measures OR physiological biomarkers) AND (cardiometabolic outcomes OR vascular outcomes) AND (work OR workplace). Additionally, within the research strategy, manual searches were made in the same primary and complimentary databases. For instance, some keywords applied were: prolonged (sitting OR standing) AND (heart rate) AND (work), (prolonged AND standing) AND TITLE-ABS-KEY (leg AND volume)), (blood pressure) AND (workplace) AND (prolonged sitting OR standing) among others, where the main emphasis was the physiological biomarker of interest. The total number of studies found for each prolonged posture are shown in (Figure 3 and Figure 4), and the number of studies included and excluded in each filter are expressed in the PRISMAS diagrams for each prolonged posture standing and sitting respectively (Figure 1 and Figure 2).

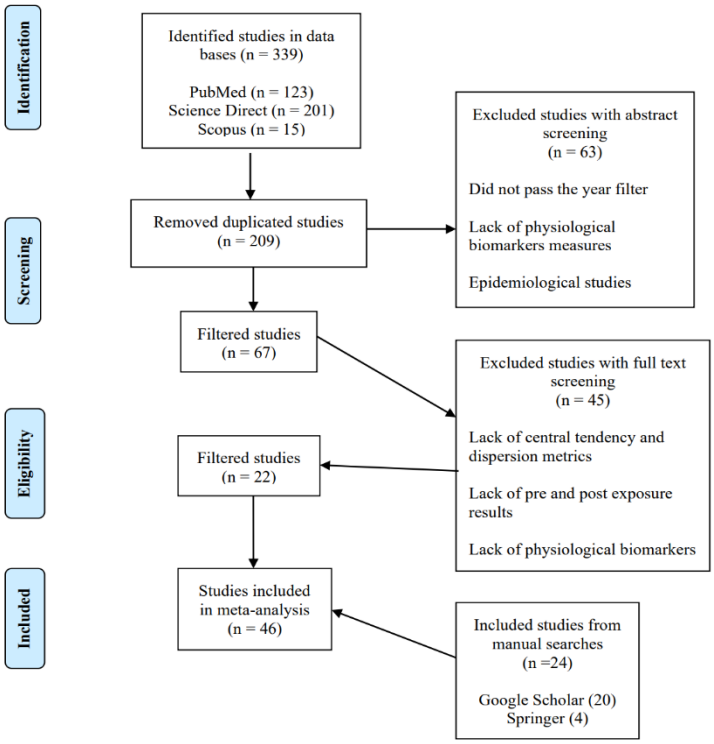

Figure 1: Prisma diagram for prolonged sitting

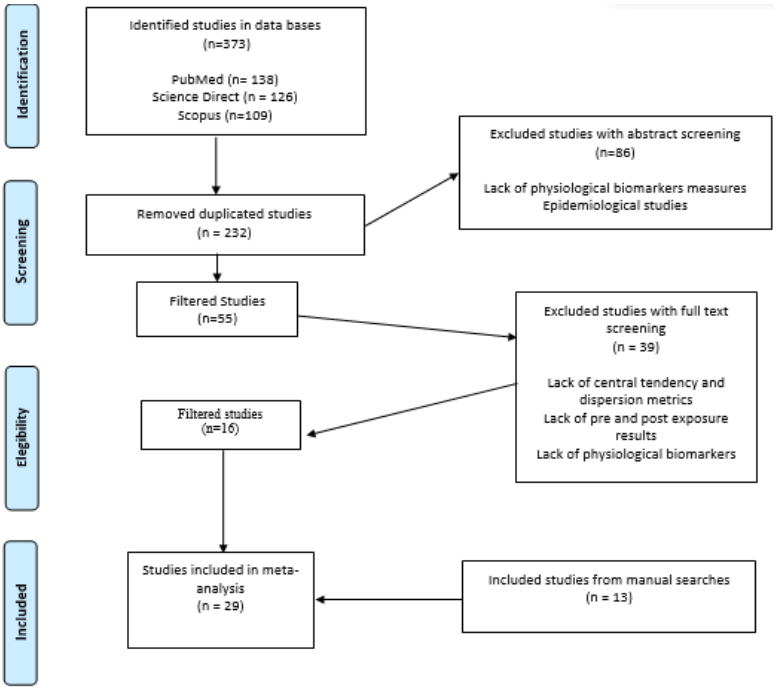

Figure 2: Prisma diagram for prolonged standing

3.3 Study selection and quality criteria in research

To ensure the quality of this study, the "Heyland Methodological Quality Score (MQS)" was used, this methodology provides a value based on a scale [0;2] and 9 criterions which evaluates different aspects of the scientific study (Diaz 2002). This methodology has a series of steps but the most important one is the comparison with a baseline criterion specifically on account that this research is based on the gauge of physiological biomarkers pre and post exposure given a period. Selected studies were chosen if they had greater than or equals 8 points, and therefore considered high quality studies (Diaz 2002).

3.4 Data recollection process

From the studies aligned with the research objective, general information such as publication year, authors, type of population, was extracted. Later, the sample population and the physiological biomarkers measures were extracted for the control group that had been exposed to the posture exposure at the beginning and at the end of the study. The data extracted from these measures were the mean and standard deviation or standard error with their unit metrics so that it could be in the meta-analysis statistical combination (Bown and Sutton 2010).

3.5 Results: included studies

Once the studies have been identified from the primary and complimentary databases, the results were expressed in (Figure 1 and Figure 2). These figures show a screening and eligibility phase. The screening phase was for the years of publication, type of posture analyzed and pre and post intervention results. Eligibility phase, however, was for the studies inclusion in the meta-analysis, those studies satisfied the inclusion and exclusion criteria, both from the primary and complimentary databases. The results were 46 studies for the prolonged sitting posture analysis and 29 studies for the prolonged standing posture.

3.6 Meta-analysis

The meta-analysis is a statistic technique that groups results from several different studies that had analyzed a common variable to define the effect size of the exposure (Huedo-medina et al. 2006) which is either prolonged standing or sitting. Each study with their respective results is quantified in the meta-analysis by estimating an effect size. One common metric is then calculated for the whole group of studies known as the global estimate of the effect size of the exposure (Durlak and Lipsey 1991). The main usage of this tool is to increase the sample results due to a limited number of publications or experiments with few participants (Israel and Richter 2011). When grouping the results from different studies, it is expected to get better decisions and inferences of an exposure. With statistical models, the degree of heterogeneity within the studies is defined and the validity of the exposure is analyzed (Higgins et al. 2003). Heterogeneity within grouped studies could be low, moderate, and high, according to the ranges 0 - 25%, 50 - 75 % y 75 – 100% respectively (Higgins et al. 2003). The present research fitted a meta-analysis of continuous outcomes given the measures of physiological biomarkers which is the result variable, under the effect of prolonged standing or sitting posture exposure. The statistic used was the mean difference and the random effects model was considered given the variability between included studies. Heterogeneity lower than or equal to 50% was desired as it shows that the included studies in meta-analysis are homogenous within themselves and therefore support the reliability of the obtained results to later have statistical confidence to conclude with the p-value (Israel and Richter 2011; Huedo-medina et al. 2006). The results are shown in (Table 1).

4. Data Collection

The following charts show total biomarkers for prolonged sitting posture (Figure 3) and for prolonged standing posture (Figure 4).

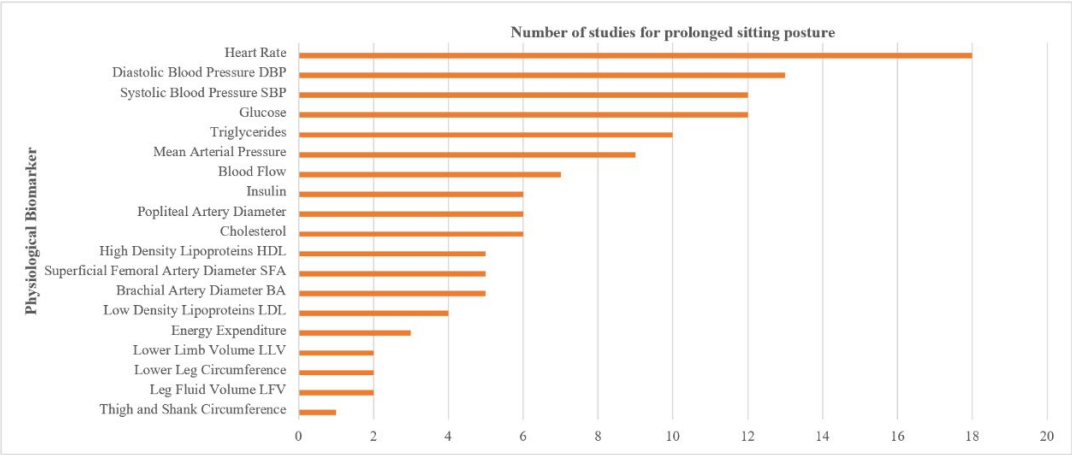

Figure 3. Total studies for prolonged sitting posture

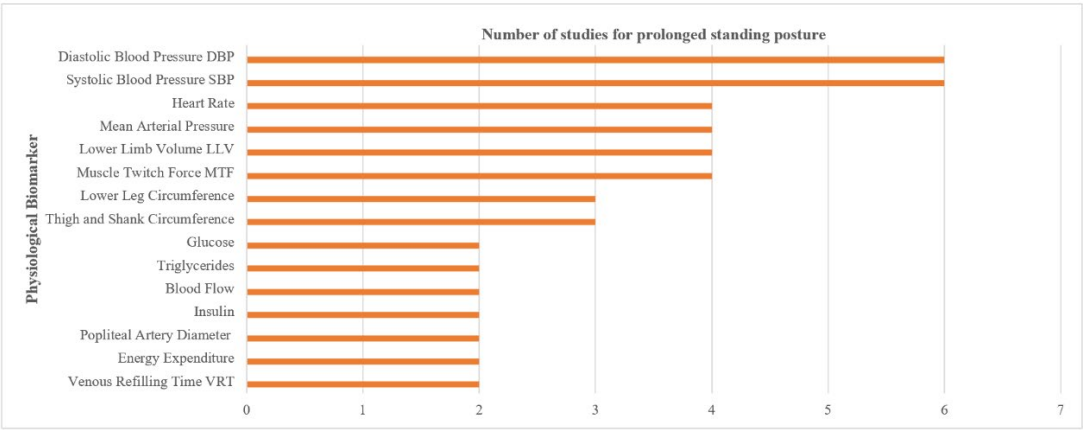

Figure 4. Total studies for prolonged standing posture

5. Results and Discussion

5.1 Numerical Results

The following results (Figure 1 and Figure 2), correspond to the total number of scientific studies found, that are going to be used in meta-analysis:

5.2 Graphical Results

A total of 42 meta-analysis were studied, and the following table (Table 1) summarizes the significant ones.

Table 1. Meta-analysis results for significative physiological biomarkers

Physiocological Biomarkers	Studies	Heterogeneity & p-value	Prolonged Posture
MTF (muscle twitch force) Amplitude - Healthy	(Wall et al. 2020); (García et al. 2015); (García et al. 2016); (García et al. 2018)	0 % ; <0.001	Standing

Mean arterial pressure - Healthy	(Morishima et al. 2017) ; (Ngomo et al. 2008) ; (Hansen et al. 1998) ; (Jacob et al. 1998)	15.09% ; 0.049	Standing
(VRT) Venous refilling time - Healthy	(Łastowiecka-Moras 2017) ; (Rocco et al. 1986)	43.86% ; <0.001	Standing
Lower limb volume- Healthy	(Blättler et al. 2016) ; (Gianesini et al. 2020) (Karimi et al. 2016)	0% ; <0.001	Standing
Lower leg circumference - Healthy	(Restaino et al. 2015) ; (Brien et al. 2021)	0% ; 0.031	Sitting
Triglycerides - Overweight	(Wanders et al. 2020) ; (Thorp et al. 2014) ; (Hawari et al. 2018)	19.57% ; 0.007	Sitting

For the following discussions, two main groups were made in order to group populations by similar characteristics. For this reason, all biomarkers were divided in healthy people, which means that the members did not present any disease, condition or limitation that could affect the study in some way, and the second group was represented by people who were overweight, and one analysis included a population with venous and swelling problems.

Prolonged standing posture

MTF Amplitude – Duration - Healthy
This Biomarker is associated to fatigue and is normally measured with electrical stimulation of the gastrocnemius, tibialis anterior and soleus muscles (Wall et al. 2020; Garcia et al. 2015; Garcia et al. 2016; Garcia et al. 2018). Results showed a statistical significance decrease which shows a reduction of muscle tension. The effect of prolonged standing posture on the biomarker had a low degree of heterogeneity of 0% which shows that grouped studies are homogeneous and reliable. However, for the MTF duration, an increase of the biomarker was evidenced and there was no statistical significance for the effect of the prolonged posture with a high 91.89%-degree heterogeneity and hence unreliable results were obtained.

Lower Leg Circumference – Healthy
Leg circumference is considered a swelling symptom and were measured with Gulik non-stretch tape (Karimi et al. 2017; Kim et al. 2021; Baker et al. 2018). Possible impact on both legs was analyzed and results showed an increase in the biomarker. However, despite having low degree of heterogeneity of 0%, there was no statistical significance of the prolonged posture in this biomarker. This biomarker not only is it related to the amount of time exposed to prolonged standing, but also to other factors such as the type of shoes used (Karimi et al. 2017) and the floor conditions to which participants were exposed (Lin et al. 2012b). In this context, there could be significant changes in swelling while changing different kind of soles and angles, as well as different strength floor conditions.

Thigh and Shank circumference - Healthy
These biomarkers are considered a swelling symptom and were measured with non-stretch tape (Lin et al. 2012a; Lin et al. 2012b; Kim et al. 2021). Reported results for both biomarkers had an increase tendency supporting leg swelling. Low degree of heterogeneity of 0% was obtained among studies, which shows that results are reliable. However, there was no statistical significance of the prolonged posture in these biomarkers. Shaikh and Shelke (2016) reported leg circumference swelling associated with 6 hours of prolonged posture exposure, which was not the case for the grouped studies where the mean exposure time was 4 hours. This is related to Javad Aghazadeh et al. (2015), who didn't report significant change in lower limbs due to less exposure time.

Systolic and Diastolic Blood Pressure - Healthy
Reported studies results evidenced a decrease for systolic blood pressure and an increase for diastolic blood pressure after exposure. Changes in blood pressure are associated to levels of hypertension and different symptoms like dizziness and fainting (Schnall et al. 1998). The biomarkers were measured in the supine position with an automatic blood pressure monitor (Kraemer et al. 2000; Ngomo et al. 2008; Liu et al. 2010; Cox et al. 2011; Jacob et al. 1998;

Malhotra et al. 2002). Results show high degrees of heterogeneity of 49.23% for systolic and 79.22% for diastolic. There was no statistical significance of the prolonged posture in these biomarkers. Included studies considered that there was a relation between work comfort and orthostatic intolerance symptoms with the static posture that is sustained during work activities (Ngomo et al. 2008; Liu et al. 2010). Similar results were reported by Laperrière et al. (2006) regarding a non-clinically significant decrease in blood pressure due to prolonged standing posture, where after the work shift a 6% decrease in the biomarker was observed in static standing jobs.

Heart Rate – Healthy

Reported studies results evidenced an increase of the biomarker after exposure and was measured in the supine position with located sensors (Kraemer et al. 2000; Ngomo et al. 2008; Hansen et al. 1998; Jacob et al. 1998; Júdice et al. 2016). This biomarker is related to cardiovascular incidences. Results showed a high degree of heterogeneity of 90.86% for the grouped studies and no statistical significance of the prolonged posture. Ngomo et al. (2008) and Kraemer et al. (2000) observed a decrease in the blood pressure with a slight decrease in the heart rate. However, Hansen et al. (1998) and Júdice et al. (2016) reported an increase in the biomarker after exposure, even though similar populations without cardiovascular or metabolic disease were studied.

Blood Flow – Healthy

This biomarker is related to endothelial vascular dysfunctions when decreasing changes are observed, this is related to the risk of peripheral artery diseases. The biomarker was measured in the supine position with ultrasound methods (Peddie et al. 2021; Morishima et al. 2017). Results showed a low degree of heterogeneity of 37.78% for the grouped studies and no statistical significance of the prolonged posture. This biomarker is related to the popliteal artery diameter and the included studies observed an increase after 3 hours of exposure which is not related to the mentioned risks.

Mean Arterial Pressure – Healthy

Increasing changes of this biomarker are associated to cardiovascular disease risk factors and the risk of myocardial infarction (Dyer et al. 1982). Statistical results reported low degree of heterogeneity of 15.09% for the grouped studies and there was statistical significance of the prolonged posture in this biomarker, thus results were reliable. Grouped studies reported an increase in the mean arterial pressure after exposure (Morishima et al. 2017; Ngomo et al. 2008; Hansen et al. 1998; Jacob et al. 1998). Similar results were reported by Mainsbridge et al. (2014) research, who reported a slightly increase in the mean arterial pressure in the control group that was not exposed to physical activity bouts interventions.

Popliteal Artery Diameter – Healthy

A low degree of heterogeneity of 0% was observed among the grouped studies and there was no statistical significance of the prolonged posture in this biomarker. The study's results analyzed hemodynamics stimuli of prolonged posture and standing was associated with a slight increase in the biomarker as well as in blood flow mentioned before in that biomarker (Peddie et al. 2013; Morishima et al. 2017). However, Peddie et al. (2013) evidenced that after 4 hours of standing, there was no longer a relation between the artery diameter increase and blood flow, but a slight increase in leg edema.

Venous Refilling Time VRT – Healthy

This biomarker is related to leg swelling and was measured with photoplethysmography noninvasive methods. Under normal conditions it is at least 25 seconds, if it is shorter there is high risk of venous chronic insufficiency (Eberhardt and Raffetto 2005). This biomarker reported a moderate heterogeneity of 43.86% between the grouped studies and there was statistical significance of the prolonged standing posture effect, thus indicating that the results are reliable (Łastowiecka-Moras 2017; Rocco et al. 1986). Both studies observed a decrease in the venous refilling time without possible incidence of venous chronic diseases.

Glucose – Healthy

Increasing changes in this biomarker are related to cardiovascular diseases as hyperglycemia and type 2 diabetes, plus there could be an association with venous disorders (Hermanides et al. 2009). In the reported studies, the biomarker was measured with blood samples analyzers. The statistical analysis reported that the included studies were not homogeneous due to de 86.64% heterogeneity level. Despite showing statistical significance of the prolonged posture,

results are not reliable because of the present heterogeneity. The included studies reported a postprandial increase in the biomarker after being exposed to prolonged standing posture (Miyashita et al. 2013; Crawford et al. 2020).

Energy Expenditure – Healthy
Statistical results evidenced an increase in the biomarker after exposure. The degree of heterogeneity showed an elevated 55.26%, therefore the results observed were not reliable. Plus, there was not statistical significance of the prolonged posture exposure. Included studies measured the indicator with respiratory gasses measured with a metabolic cart (Tyton et al. 2018). Nevertheless, Tyton et al. (2018) concluded that there was an increase in this biomarker due to the posture and a slight 5% increase of energy expenditure was reported in (Júdice et al. 2016). The results variability affecting the high degree heterogeneity could be explained by a greater expenditure in (Tyton et al. 2018) than (Júdice et al. 2016) in the meta-analysis.

Lower Limb Volume – venous and swelling problems
This biomarker is associated to leg swelling and its venous disorders implications when increasing changes are reported (Restaino et al. 2015). However, the present results evidenced a decrease in the biomarker. It was measured with water displacement methods and non-stretch tape. For this biomarker a high degree of heterogeneity of 99.92% was observed, hence obtaining unreliable results. There was not statistical significance of the prolonged posture exposure. However, Kim et al. (2021) reported that after 8 hours of work shift, there is a significant change in edemas, lower limb pain and swelling. The author explains that these changes except for pain could be alleviated with compression hosiery during work. Likewise, Zander et al. (2004) concluded specifically on leg edemas to be the result of prolonged standing posture and unlike (Kim et al. 2021), he proposes the use of ergonomics mats which could slightly improve the problem.

Lower Limb Volume – Healthy
For this biomarker, it was observed a low degree of heterogeneity of 0% for the included studies. Plus, there was statistical significance increase of the prolonged standing posture exposure in this biomarker, which therefore shows that this kind of postures has an effect on the lower limbs swelling in a healthy population without any prior symptoms of leg edema or obesity. Common measures procedures are water displacement methods (Kim et al. 2021), new technological instruments (Blättler et al. 2016) and mathematical formulas as the truncated cone (Gianesini et al. 2020; Karimi et al. 2016). The observed results are similar to the ones found by Karimi et al. (2016), where leg swelling, and pain affects healthy non obese individuals' lower limbs because of prolonged standing. The author analyzes that the problem could be alleviated by using shoes with irregular and not flat soles. Similar results were obtained by Blättler et al. (2016), however he proposes an improvement when using compression stockings.

Insulin – Healthy
Increasing changes in this biomarker could be associated to cardiovascular diseases and type 2 diabetes (Champion et al. 2018). Reported studies measured the biomarker by blood samples analyzers. The statistical results are not reliable because of the high degree of heterogeneity of 98.90% and lack of statistical significance of the prolonged posture exposure. The statistical results reported an increase in the biomarker after exposure. In this context, Crawford et al. (2020) reported first that insulin measures do not differ statistically in prolonged standing or sitting. Second, the author evidenced a slight increase in the biomarker when being exposed to prolonged exposure. On the other hand, a higher increase in the biomarker was found in (Miyashita et al. 2013). This differences in the reported results from the studies, are a prior reason for the variability included in the meta-analysis, which was evidenced in the high degree of heterogeneity.

Prolonged sitting posture

Lower Leg Circumference - Healthy
This biomarker is associated to leg swelling and was measured with non-stretch tape. Results showed an increase of the biomarker after exposure and compared to prolonged standing previously analyzed, there was statistical significance and a low degree of heterogeneity for the prolonged sitting posture exposure, which shows that results were reliable. Obtained results could be associated with other limb volume biomarkers. Kim et al. (2021) reported an increase in extracellular leg fluid, calf, thigh and ankle circumference due to 8 hours of prolonged posture intervention. Other related biomarker is the leg blood flow studied by Brien et al. (2021) who evidenced a decrease in the blood

flow per hour. It is worth noting that similar results were reported by Kraemer et al. (2000), who evidenced leg swelling in volume and increase in calf circumference.

Leg Fluid Volume – Healthy

This biomarker is associated to leg swelling and can be measured using a bioelectrical impedance (Singh et al. 2017; Vena et al. 2016). After the meta-analysis, this biomarker reported a reliable heterogeneity level of 13.77%, giving confidence to conclude with the p value, which showed no statistical evidence of the prolonged standing posture effect over the biomarker in healthy patients. During this research, it was found other articles which conclude that there was not significant difference between the baseline measures and the post intervention measures after being seated for a prolonged period, at the end, it was said that the effect is significant once the person stands up to perform other activities (Singh et al. 2017). During the research, the meta-analysis showed an increase in this biomarker, even it was not significant, which is not good because this is associated to leg edema or even blood clots who can cause more severe problems (Vena et al. 2016).

Systolic Blood Pressure – Overweight and Healthy

This biomarker is associated to diabetes and cardiovascular diseases, to measure this biomarker an automatic blood pressure monitor can be used (Penning et al. 2017). For this biomarker, the results of the meta-analysis showed homogeneity between the grouped studies for this biomarker 0% in overweight patients but gives certainty about the conclusion with the p value for the effect, which showed that there is not statistical evidence that that the biomarker in affected by this prolonged position. In the other hand with healthy patients there was a high heterogeneity which doesn't give reliability of the conclusion with the p value, which resulted not significant. Studies like Dogra et al. (2019), which used for the analysis healthy people, showed that there was a small increase of the biomarker between the baseline and the post intervention. At the same time, Lee and Wong, (2015) made a study making no difference between healthy people and overweight people, at the end, the results showed an increase of 0.06mmHg after the prolonged sitting posture. These conclusions are associated to the results of the meta-analysis for this biomarker in both populations, because an increase was evidenced, which is not positive because it can lead to future cardiovascular diseases (Wennberg et al. 2016; Penning et al. 2017).

Diastolic Blood Pressure – Overweight and Healthy

This biomarker can be measured using an automatic blood pressure monitor (Penning et al. 2017). The results obtained showed homogeneity 0% for overweight population, but at the same time, it resulted in a high heterogeneity for healthy people 98.66%. About the p value for both populations in the meta-analysis, the results showed that there is not statistical effect of the prolonged sitting posture in the diastolic blood pressure biomarker. The studies used of healthy patients, showed increments in the levels of diastolic blood pressure, and this was concluded in another available meta-analysis where healthy patients were measured as well, where this biomarker rise 0.20 mmHg (Lee and Wong 2015). In the other side, in the case of overweight patients, the results of some studies were different, because this biomarker decreased, but it was because of active breaks (Bhammar et al. 2017). The increase or decrease of this biomarker is associated to future cardiovascular diseases, in the case that it increases, it can lead to vascular hypertension, but in the opposite case, if diastolic blood pressure decreases 0.20 mmHg the associations are dizziness and even fainting (Fagard et al. 2007).

Heart Rate – Overweight and Healthy

To measure this biomarker sensors can be used (Ngomo et al., 2008). Moreover, for this biomarker, the results showed homogeneity between the studies 0%, and there was not statistical evidence of the effect of the prolonged position in the biomarker for overweight people. Conclusions like these, were obtained in other studies as well, where heart rate was maintained near normal status (Wennberg et al. 2016). In the other side, in the case of healthy people, the heterogeneity level was 91.07% which did not give statistical confidence for concluding about the effect of the sedentary position. Despite this, Altenburg et al. (2019) said that heart rate in prolonged sitting position was lower than in prolonged standing position because of the energy spent in the activity. For this analysis, heart rate in overweight and healthy people increased, which can lead to tachycardia (Perret-Guillaume et al. 2009).

Popliteal Artery blood flow – Healthy and Overweight

This biomarker can be measured using the duplex-Doppler ultrasound (Morishima et al., 2016). The results of the meta-analysis for the homogeneity test are not reliable for both populations, healthy 90.54% and overweight 87.52%, for this reason the conclusion with the p value cannot be made without first confirming the origin of the variability. The studies included in the meta-analysis, reported a decrease in the blood flow after the sedentary posture for both populations. This decreasing can be linked to peripheral artery diseases or endothelial vascular dysfunctions. Paterson et al. (2020) concludes similar results, where a decrease in FMD% was evidenced, associated with a decrease in blood flow during prolonged sitting posture.

Triglycerides - Healthy and Overweight

To measure this biomarker, spectrophotometry can be used, using the lipase hydrolysis method (Champion et al. 2018). In the case of the overweight population, the heterogeneity level was 19.57% and a significant effect of the prolonged posture in the biomarker using the p value was obtained, concluding with this, that there is an effect of the prolonged posture over the biomarker. In the case of the healthy population, a high level of heterogeneity was obtained 97.55%, which do not give confidence for concluding an effect. The increase of the biomarker in the overweight population was concluded in other studies as well, where overweight people were not exposed to any external intervention (Loh et al. 2020). As a whole, this biomarker increased, which can lead to cardiovascular diseases and type 2 diabetes (Champion et al. 2018).

Cholesterol – Healthy

To measure this biomarker, a blood sample analyzer can be used (Dogra et al. 2019). The results obtained after the meta-analysis showed high homogeneity 0%, and a significant effect of the prolonged sitting posture in the biomarker. The results of the study showed an increase in the biomarker after the exposure. Bailey and Locke (2015) performed an experiment about the effect of prolonged sitting in cholesterol, even by considering actives breaks, and the results were the same as the one concluded in this analysis, the biomarker was not affected. The increasing of this biomarker elevates the probabilities of a heart disease (Dogra et al. 2019).

High- and low-density lipoproteins (HDL, LDL) - Healthy

To measure this biomarker, a blood sample analyzer can be used (Dogra et al. 2019). High homogeneity was evidenced in both biomarkers 0%, but there was not statistical effect. A decrease in both biomarkers was evidenced after the exposure to the prolonged sitting posture. Considering the decrease of this biomarker, it can be linked to atherosclerotic cardiovascular disease and even different types of cancer (Sung et al. 2019). Moreover, Bailey and Locke (2015) performed several experiments, considering active breaks during the prolonged sitting posture, but during the exposure time, the conclusion was the absence of the effect of the posture over the biomarker.

Blood pressure- Healthy

To measure this biomarker an automatic blood pressure monitor can be used (Penning et al. 2017). The statistical analysis showed low heterogeneity 33.26% between the studies gathered for this biomarker, but not statistical evidence of the effect of the prolonged posture. By analyzing the graphic of the meta-analysis of this biomarker, the global estimate parameter is negative, which shows that there was an overall increase of this biomarker in the analysis during the prolonged posture for this population, this increase can cause different cardiovascular diseases (Fagard et al. 2007). The conclusion is correlated with other studies, where white collar workers were exposed to uninterrupted sited work, and during week number 13, a small increase was noticed in the blood pressure biomarker (Mainsbridge et al. 2014).

Superficial femoral artery diameter (SFA) - Healthy

To measure this biomarker, a duplex-Doppler ultrasound can be used (Restaino et al. 2015). The results obtained, showed homogeneity 0%, but not statistical significance of the exposure. The results from the meta-analysis, showed a decrease in this biomarker after the exposure. The changes of this biomarker are associated with possible vascular dysfunctionalities of lower extremities, because of the decrease in the blood flow and %FMD (Thosar et al. 2015).

Brachial artery diameter BA – Healthy

To measure this biomarker, automated sphygmomanometer can be used, or a duplex-Doppler ultrasound (Restaino et al. 2015). The results from the meta-analysis, showed homogeneity 0%, but the effect the prolonged sitting posture over the biomarker was not significant. Restaino et al. (2015) as a conclusion of his experiment, showed a not significant statistical difference between the baseline values and the post exposure values, this is because in the brachial artery is more resistant to negative effects of the prolonged exposure of the sitting posture (Carter and Gladwell 2017). The meta-analysis of this study showed an increase of this biomarker, with can be associated to vascular dysfunctions in upper extremities (Thosar et al. 2014).

Popliteal artery diameter – Healthy

To measure this biomarker, duplex-Doppler ultrasound can be used (Restaino et al. 2015). A high heterogeneity was obtained from the meta-analysis 89.98%, and lack of statistical evidence of the effect of the prolonged exposure over the biomarker. This biomarker is related with the blood flow, because the results showed a decrease in the diameter, and because of this, the flow was affected as well. The decrease of this biomarker is associated to the risk of vascular dysfunction in low extremities (Restaino et al. 2016).

Glucose - Healthy and Overweight

To measure this biomarker, blood samples analyzers can be used (Miyashita et al. 2013). The results for both, healthy and overweight participants, the meta-analysis showed no homogeneity 95.12% and 99.67% respectively, without the confidence of this parameter in the appropriate range of homogeneity, there is not reliability to conclude about the effect with the p value, which was significant for healthy people and not significant for overweight people. Moreover, the studies showed an increase in glucose levels after the exposure. Minghui et al. (2020) meta-analysis results, showed that uninterrupted sitting posture did not represent attenuation on the studies considered. At the same time, Loh et al. (2020) says that moderate paused breaks during workday, reduces the risk of chronic diseases like type 2 diabetes and cardiovascular diseases when glucose is high.

Energy expenditure – Healthy

It is possible to measure this biomarker with respiratory gasses using a metabolic cart (Tyton et al. 2018). The heterogeneity level of this biomarker was 37.23%, but the meta-analysis showed not statistically evidence of the effect of the exposure. Júdice et al. (2016) says that there is not statistical difference in the effect of energy expenditure, between active workstations 5% and prolonged sitting posture 8%. Moreover, energy expenditure increases while being seated, but it is not statistically significant compared to the energy that is expended in standing up constantly as an active break (Júdice et al. 2016). Despite this, the increment of this factor can lead to constant fatigue (Wennberg et al. 2016).

Insulin - Healthy and Overweight

Reported studies measured the biomarker by blood samples analyzers (Champion et al. 2018). The results for both populations, healthy and overweight, the meta-analysis showed no homogeneity (98.91% and 97.62%). Additionally, there was not statistical evidence of the effect of the prolonged exposure in both cases in this biomarker. The results of the included studies reported an increase in the biomarker after the exposure. Increasing changes in this biomarker could be associated to cardiovascular diseases and type 2 diabetes (Champion et al. 2018). Minghui et al. (2020) support this conclusion, where a postprandial reduction in this biomarker was evidenced. Penning et al. (2017) says that there is not statistical evidence to say that insulin changes after sedentary postures (prolonged sitting posture), and that there should be considered other factors in workdays, like high fat food.

Low Limb Volume – Healthy

Common measures procedures are water displacement methods (Kim et al. 2021), new technological instruments (Blättler et al. 2016) and mathematical formulas as the truncated cone (Gianesini et al. 2020; Karimi et al. 2016). The results showed reliable homogeneity 0%, but absence of statistical significance of the exposure over the biomarker. The results of the studies showed an increase in the biomarker after the exposure, this biomarker is associated to leg swelling and its venous disorders implications when increasing changes are reported (Kim et al. 2021). The increase

of this biomarker is related to leg fluid volume and circumference, in which all resulted on an increase because of the prolonged sitting posture.

5.3 Proposed Improvements

The existent literature ensures that I^2 statistic should be the first analysis to conclude on the effectiveness of gathering the studies that have common characteristics. Then the p-value should be analyzed to conclude on the significant effect of the prolonged posture exposure on a physiological biomarker. If the parameter I^2 surpasses the 50%, there is no statistical support that the included studies have an adequate variability between 0% and 50 % (Oliveros 2015) and there is extra variability that should be analyzed. This variability analysis requires enough time to separate the studies more effectively or gather more studies so that they could be included differently (Fernandez Chinguel et al. 2019). High percentages of heterogeneity should be analyzed thoroughly, not only with population characteristics but also an adequate monitoring of the biomarker that could with a short-term focus as in this investigation or long-term analysis (Schnall et al. 1998; Mainsbridge et al. 2014). Plus, there should be considered the techniques and equipment that differ according to the objectives of a project (Paterson et al. 2020) and the ergonomics risks associated with each posture and assigned task (Alias et al. 2020). In this context, the endeavors to explain high degrees of heterogeneity corresponds to an exhaustive analysis of included studies in the meta-analysis.

5.4 Validation

The analysis was executed with a 0.05 significance level which means if the effect p-value result was lower, there was an effect of prolonged posture in a particular physiological biomarker. The degree of heterogeneity considered low, moderate and high was evaluated according to accepted common ranges that were previously mentioned in the meta-analysis section. Those results with heterogeneity levels lower than 50% are considered homogeneous and therefore explains a greater effectiveness of the meta-analysis.

6. Conclusion

Physiological biomarkers measures are important when studying the human body and its possible health effects, specifically when analyzing different types of work tasks. Like mentioned before, humans tend to spend 50% of their time in the same posture, which contributes to a global problem. Having said this, the systematic literature and meta-analysis proofed that some physiological biomarkers are affected during prolonged sedentary postures and in long term periods those implications could be associated to cardiovascular diseases and musculoskeletal disorders.

The physiological biomarkers analysis with a reliable significant degree of heterogeneity and significantly affected by prolonged sedentary standing and sitting postures are shown as the following: for prolonged standing posture, muscle twitch force amplitude MTF, lower limb volume, mean arterial pressure and venous refilling time were found significant for the healthy population analysis. On the other hand, for prolonged sitting posture, it was reported an effect on triglycerides, for the overweight population analysis and lower leg circumference for the healthy population analysis. These biomarkers results could explain a certain degree of causality with cardiovascular and musculoskeletal diseases; for this reason, future epidemiological investigations should focus thoroughly on explaining this possible correlation.

The investigation made, is a guide for future researches where external interventions can be tested in the labor context for example by changing: type of footwear, floor, active breaks, compression stockings, etc. In the way that physiological biomarkers could be least affected, giving that their increase or decreased caused by sedentary postures can be linked to future cardiovascular and musculoskeletal diseases.

This research got some analysis with high heterogeneity, which explains the lack of studies to obtain robust conclusions. The total number of studies found was divided for each physiological biomarker and for each posture, thus having some sample powers greater for some biomarkers than others. In this context, this explains the lack of existent literature associated with the main objectives of this investigation.

The grouped studies in the statistical combination, analyzed physiological biomarkers measures in times similar to a work shift schedule and changes in the biomarker were evidenced. However, it is important to consider long term physiological biomarkers measures due to variability in the population’s characteristics and different work tasks that

exist in the manufacturing and service industries. Some existent meta-analysis and research studies have monitored the biomarkers throughout a longer period greater than a work shift. However, this long-term monitoring does not guarantee the whole control of the included participants.

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