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EXERCISE, AGE AND SPORT EFFECTS ON VENOUS COMPLIANCE

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Juliane Poock Wallace, Chair

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DEDICATION

The dedication, to myself, is a personal dedication of one's work.

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CHAPTER 1

INTRODUCTION

The ability of veins expands to accommodate changes in blood volume is called venous compliance. Veins are blood vessels that are extremely flexible. They can hold large amounts of blood without experiencing significant pressure increases. Veins are more flexible than arteries because they have thinner walls and less smooth muscles. This allows them to expand in response to an increase in blood volume. The regulation of blood pressure, blood flow and other functions are affected by venous compliance, such as in some cardiovascular diseases, can cause decreased blood flow and pressure. In contrast, if venous compliance increases, such as in exercise or as a result of certain medications, blood flow is improved and blood pressure drops.

Appropriate regulation of venous blood volume is critical during various physiological stressors (i.e., hemorrhage, orthostatic challenges) to maintain cardiovascular homeostasis and blood pressure (Young, C., et al, 2006). The venous compliance of the extremities is a major determinant of the amount of blood that may be translocated to the central region, because small changes in peripheral blood volume can greatly impact cardiac filling pressure and subsequently cardiac output (Young, C., et al, 2006). Aging, exercise, current fitness status and training can cause physiological changes in the body that can also alternate venous compliance in the body.

Aging and habitual endurance exercise are two chronic physiological states that may influence leg venous compliance (Monahan, K., et al, 2001). Aging is associated with a reduced leg venous compliance (Hernandez, J.P., Franke W.D., 2003). Our blood vessels, including our veins, lose some of their flexibility as we age. They also become less flexible. The mechanism(s) causing age-related declines in compliance is not known.

Structural alterations, such as venous wall thickening and increases in collagen-to-elastin ratio, similar to what is seen in the arteries, may reduce venous compliance (Young, C., et al 2006).

On the other hand, endurance exercise is an established intervention for the improvement and maintenance of venous vascular health. When a person experiences physiological stress such as that during exercise, changes in venous volume, venous compliance, or both can cause a shift in blood volume from the veins to the heart. This shift in blood volume via the venous system plays an important role in circulatory regulation, including the maintenance of blood pressure (BP) and cardiac output. This has been reported by Hernandez and Franke (2004) that venous compliance and volume is higher in exercising limbs.

There have been different exercise training methods such as KAATSU but also short-term and long term endurance programs that applied in researches. KAATSU, which is an exercise combined with blood flow restriction (BFR), is one of method of trainings that uses a specially designed belt tightened near the joints of the upper. arm or leg, applying pressure to the muscle and temporally restricting blood flow (Iida, H., et al, 2010). Research has shown that low intensity KAATSU training can induce muscular hypertrophy (Takarada et. al. 2002). Abe et al. (2006) found that slow walking combined with muscle BFR can induce increases in muscle strength and size, despite a low level of intensity. Slow walking with BFR can be an effective way to increase muscle hypertrophy, especially in the elderly (Iida, H., et al, 2010). Slow walking with BFR reduces arterial flow and causes venous blood to pool in the leg vein (Takano, et. al. 2005; Iida, et. al. 2007). These changes could result in hydrostatic forces within the leg vein (Iida, H., et al, 2010).

Orthostatic stress is the stress that occurs when someone stands from a seated or lying posture. This can cause a drop in blood pressure or an increase in heartbeat. The cardiovascular system's response to orthostatic stress is affected by how the venous compliance works. Orthostatic stress can be reduced by regular exercise that increases venous compliance. Regular exercise can improve the veins' ability to stretch and adapt to changes in blood volume. This may help maintain blood flow to the heart and prevent blood pressure from dropping during orthostatic stress. Evidence suggest that resisted trained men have increased leg compliance and would tolerate the orthostatic stress better than sedentary men.

To summarize, aging, exercise, muscular fitness level and resistance training are some of the factors that affect venous compliance either negatively or positively. With that being said, the objective of this review is to assess which physiological an external factors influence venous compliance. This review will address the questions down below;

- Does resistance training affects venous compliance and if does, is there any difference between short term/ long term/interval/ continuous trainings?
- How does aging influences the venous compliance and can the negative effects of aging be decreased with resistance training?
- Is there any relationship between muscular fitness level and leg compliance?

Since gravity is partly reason of orthostatic stress, does runners and swimmers have different tolerance to orthostatic stress, and as a result any difference in leg compliance?

CHAPTER 2

METHODS

The Preferred Reporting Items for Systemic Reviews and Meta- Analyses (PRISMA) approach was used to report the retrieval and selection of articles review. With respect SIU Morris Library Kinesiology and Exercise Science Links were used as a data base source to search for existing Randomized Controlled Trial and Clinical Trial. I searched PubMed and Web of Science using terms “*Venous compliance*” in ANY FIELD and “*Venous compliance and exercise/age/sport*” in any field. After selection the sample of articles, the researcher used their Citations as a secondary data source.

In the first stage of screening, research was narrowed it down by using terms *Venous Compliance and Exercise/Age/Sport*. In the second stage of screening under the advanced search: (1) Published in English, (2) Identified randomized controlled trial, (3) Clinical trial were chosen as a considered inclusion criterion for articles. In the last stage of process, papers were excluded based on their title or abstract if they did not clearly report on venous compliance or venous compliance with exercise/age/sport, and also duplicates were removed. Then, chosen articles retrieved from the link that is provided by the PubMed and Web of Science. At both stages papers were retained if there was insufficient information to exclude them.

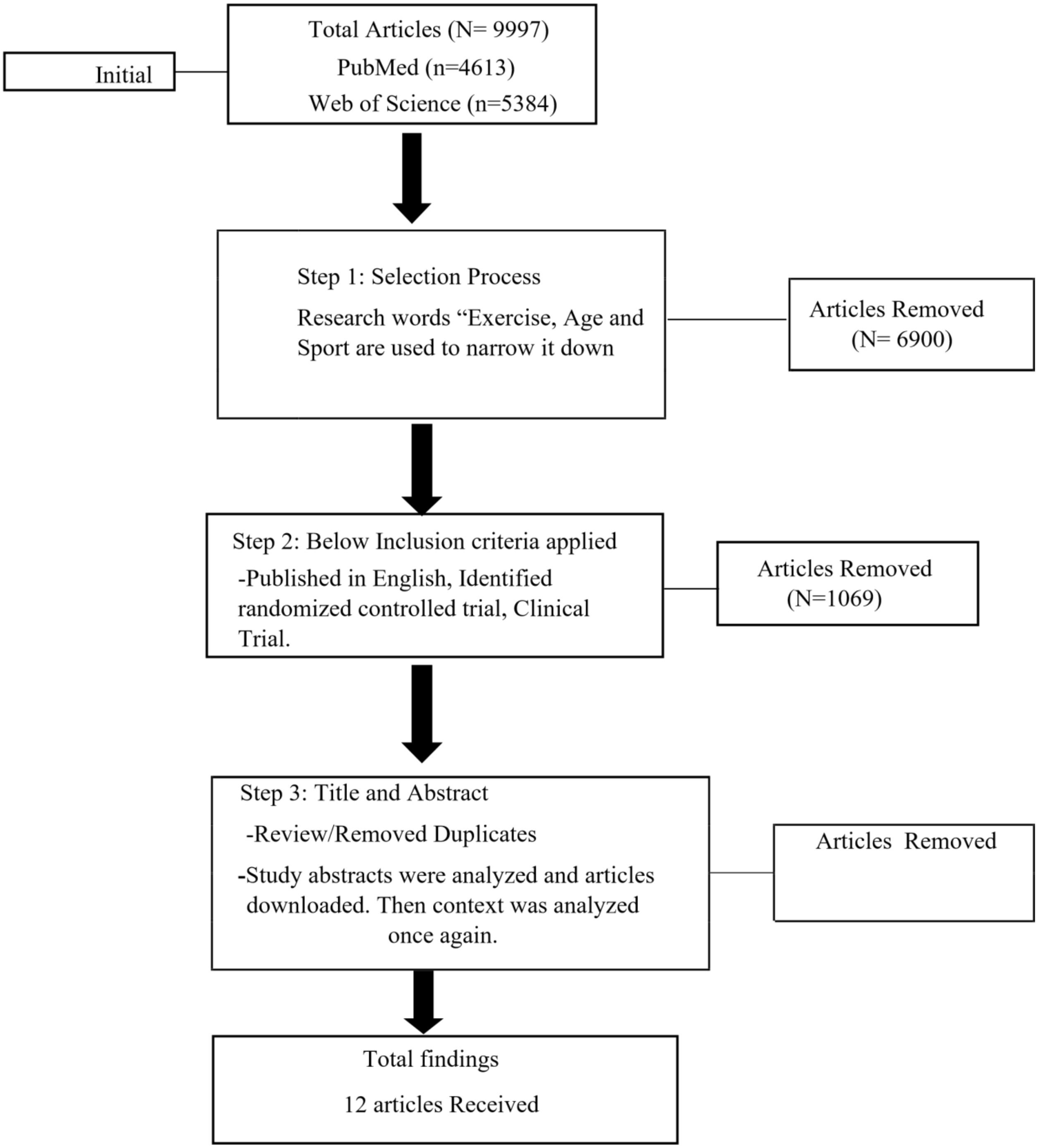

Figure 1. Methods

CHAPTER 3

RESULTS

The initial research criteria returned 9997 articles (4613 from PubMed and 5384 from Web of Science. The search term Venous Compliance Exercise/Age/Sport helped me to finalize research ideas. I reviewed abstracts for inclusion based on the stated criteria. Of the returned articles, 11 of them met the inclusion criteria. Articles were separated into different groups; venous compliance and age (Table 2, N=3), venous compliance and exercise (Table 1, N=6), venous compliance and sport (N=1), and venous compliance to fitness background (Table 3, N=2).

Venous compliance is defined as the change in venous volume (ΔV) in relation to the change in stretch pressure (ΔP, compliance = $\Delta V/\Delta P$). The higher the compliance, the greater the volume change for a given pressure change. It is known that vascular compliance declines unexpectedly with age since aging is affecting the structure of the venous wall.

Table 1

Venous Compliance and Exercise

Authors	Type of Study	Major Findings
Fahs and et change **al (2013)**	Experimental	Low-load BFR resistance training did not venous compliance
Haruko and people **Et al (2011)**	Experimental	6 weeks of slow walking with BFR in elderly significantly improved leg venous compliance
Yasuhiro And et al (2022)	Experimental	Acute exercise does not improve venous compliance in both exercising and non-exercising limbs 60 min after the intervention
Hernandez and Franke (2004)	Experimental	6 months of endurance training program tended to improve venous compliance in older individuals
Anna et al (2019) continuous intensities	Experimental	8 weeks of endurance training increased calf venous compliance in young adults by not moderate exercise but interval exercise at low and high
Fahs and better **Et al (2013)**	Experimental	Recreationally-active middle age adults have a calf venous compliance in the preferred limb.

It has been approved that consistent exercise improved venous compliance. Hernandez et al (2004) found that 6 months of training program may improve venous compliance. Anna et al found that 8 week of interval endurance training had positive effects on leg compliance. On the other hand, Iimura et al (2022) found that acute exercise does not improve venous volume and compliance in both exercising and non-exercising limbs. The method of blood flow restriction is combined with KAATSU training method to see the effects on leg compliance. Iida et al (2011) found that 6 weeks of walking exercise with BFR may improve limb venous compliance in untrained elder female subjects. Fahs et al (2014) only applied BFR on their subjects and what they had found is there was no change in venous compliance after short-term low-load resistance training

Table 2

Venous Compliance and Fitness level

Authors	Type of Study	Major Findings
Convertino and Et al (1988)	Experimental	Muscled CSA is a significant contributor of the leg compliance and leg compliance is less when there is a large muscle mass providing structural support
Kawano and Et al (2010)	Experimental	Resistance-trained men have greater forearm venous compliance than age-matched sedentary controls

As for the venous compliance and exercise fitness level, Convertino et al (1988) found that when there is a large muscle group providing support to the area, leg compliance is tended to be lower. Kawano et al (2010) found that resistance trained men have a greater forearm than age matched sedentary men.

Table 3

Venous Compliance and Aging

Authors	Type of Study	Major Findings
Young and Et al (2006)	Experimental	Calf and forearm venous compliance in lower in older adults and the reason is probably due to structural alterations in the venous wall
Monahan and Et al (2001)	Experimental	Calf venous compliance is reduced with age in sedentary and endurance-trained men due to effects of aging but preserved better in older-resistance trained men

Hernandez and Franke (2004)	Experimental	Venous compliance reduced with age and increased with improved fitness level.

It is known that aging effects venous compliance negatively. Monahan et al (2001) found that calf venous compliance is reduced with age in sedentary and endurance-trained, but compliance is better preserved in endurance-trained me. Young and et al (2006) had similar results (lower forearm venous compliance in older adults at rest) and also they added that aging effects on venous compliance due to the structural alterations. Hernandez et al (2004) proved that aging reduces venous compliance and their active in both young and older participants and a decreased venous compliance with age in both fitness categories.

Lastly due to the effect of gravity, swimmers and runners has different type of resistance training loading on their body. Wallace et al (2012) compared swimmer and runner calf venous compliance. The results indicate that runners had a greater calf venous compliance than swimmers.

CHAPTER 3

DISCUSSIONS

Monahan et al (2001) found that calf venous compliance is reduced with age in both healthy sedentary and endurance-trained men due to the primary effects of aging. Hernandez et al (2004) have the same findings regarding the relationship between aging and venous compliance. Individuals age over 60s and younger than 30s compared in the study and the findings show that venous compliance reduces with aging and aging factors. Even though aging reduces lower-body venous compliance, it is known that training or chronic training can increase venous compliance. In the same research, Hernandez et al (2004) also looked at if there were any differences between people at different fitness levels. They have found "an increased compliance with fitness with both young and older participants and a decreased venous compliance with age in both fitness categories".

Young et al (2006) found similar results compared to other studies. Their reports indicate that "calf and forearm venous compliance is lower in older adults at rest". Also, they mentioned that "forearm venous compliance is higher in young and older adults compared with calf venous compliance".

As I mentioned before, training can elevate lower-body venous compliance. People who are exposed the chronic training are expected to have higher vascular compliance compared to those who are sedentary. Convertino et al (1988) investigated the relationship between leg compliance and fitness-related muscle properties such as leg musculature and leg strength. They found in 10 healthy males that muscle mass and calf cross-sectional area contributed most significantly to explaining variations in leg compliance.

Kawano et al (2010) compared the forearm venous compliance between resisted-trained and sedentary men who are of the same age. The finding shows that resisted-trained men have greater forearm venous compliance than sedentary age-matched controls. The reason behind that might be explained by greater forearm venous capacitance.

Training unilaterally or preferred arm can affect blood flow and strength. While this claim is proved in documents on upper limbs, there have been only a few studies documented about lower limbs. Fahs et al (2013) examined muscular and vascular function in middle-aged populations who are recreationally active. It has been found that limb preferences affect vascular function and calf venous compliance tends to be higher in the preferred limb. The reason behind that is exercise training diminished the age-related decline in venous compliance in the preferred limb.

Besides these studies, there have been papers where an exercise program had been applied and the venous compliance effect was recorded. Hernandez et al (2004) did a study of 6 months of endurance training effects on venous compliance. 20 participants both men and women completed 6 months of the aerobic training program. Calf venous compliance was recorded at the end of 3 and 6 months. Even though the results at the end of 3 months were not different between of group trials, venous compliance tended to be greater for the exercise group after 6 months of endurance training.

In addition to the effects of long-term endurance training, short-term endurance training has been investigated as well. Oue et al (2019) applied an eight-week endurance exercise training on young healthy volunteers. The exercise program included interval and continuous groups. After the 8-week program calf (exercising limb) and forearm (non-exercising limb), venous compliance was recorded.

Results pointed out that, the interval exercise group had increased calf compliance while the continuous group had no change in either calf or forearm compliance. This means that interval exercise at low and high intensities can increase venous compliance on exercising limbs and but adaptations to 8-week endurance training with moderate continuous exercise might not be enough to affect venous compliance on working limbs.

Considering the fact that long and short-term endurance training has effects on venous compliance, it is unknown if acute exercise has effects on venous compliance as well. Iimura et al (2022) executed acute endurance exercise training to see if there is an increase in venous volume and compliance. They have recorded the compliance in the calf and forearm and results show that there was no change between and 60 min after acute endurance exercise whether it is continuous or interval workloads. This led to the suggestion of applying acute endurance exercise for at least 6-8 weeks to be able to see the effects on venous compliance.

As it is proved that endurance training can affect venous compliance, different types of modalities are combined with endurance exercises and one of those methods is applying endurance exercising with blood flow restriction. This is also called the KAATSU exercise. Existing research points out that KAATSU training induces muscle hypertrophy and strength gains. Iida et al (2011) applied this method to 16 elderly people for 6 weeks. At the end of 6 weeks, slow walking with blood flow restrictions notably rose limb venous compliance in elderly people. This can be a new method to use in elderly women rather than endurance training. However, further research is required to make the underlying mechanics clear.

Meanwhile, what Fahs et al (2014) found conflicted with other researchers, they applied low-load resistance training (knee extensor training) with or without blood flow restrictions to middle-aged men and women for 6 weeks. There had been no change in calf venous compliance in either limb after the training. While these two research had different training methods combined with blood flow restrictions, this data suggests that other types of exercise training may be needed to combine with resistance training to see the improvements

Lastly, endurance exercise training had proven itself about improving venous compliance, but the mode of endurance training effects on venous compliance is unknown. To further analyze that Wallace et al (2012) compared elite swimmers to runners. 20 highly trained athletes have undergone different measurements including calf venous compliance. The data showed that runners had higher calf venous compliance than swimmers. The underlying mechanism is not clear but it has been suggested that the training environment (gravity vs microgravity) plays a role for the reason of having higher calf compliance in runners than swimmers.

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