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Bachelor's thesis

BACHELOR'S THESIS

Time efficient strength training: The effects of agonist-antagonist supersets versus traditional strength training.

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Norwegian University of
Science and Technology

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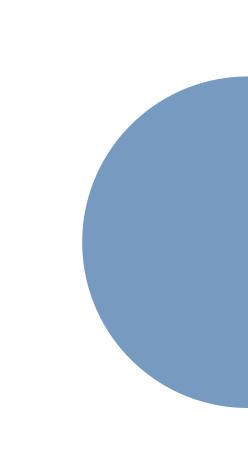Time efficient strength training: The effects of agonist-antagonist supersets versus traditional strength training.

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Sammendrag

Bakgrunn: Helsemessige gevinster av trening er godt kjent, men prioriteringen av trening kan ofte være vanskelig ettersom det kan være tidkrevende. Dette studiet undersøker effektene agonist-antagonist superset trening har på tidseffektivitet, treningsvolum, oppfattet utmattelse, hypertrofi og styrke. **Metode:** Artiklene ble hentet fra PubMed, Oria og Google scholar i perioden 20.02.21 til 10.3.2021. Utvalget var mellom 18 og 40 år og betraktet som friske mennesker. Studiene måtte være randomiserte og bestå av en superset gruppe og en kontrollgruppe som gjennomførte tradisjonell styrketrening. **Resultat:** 8 studier ble inkludert i dette litteraturstudiet. Studiene viser at man gjennom bruk av superset kan oppnå likt eller høyere volum på kortere eller lik tid som ved tradisjonell styrketrening, uten at det øker oppfattet utmattelse. Det var få funn på styrke og hypertrofi. **Konklusjon:** Basert på de inkluderte studiene er det grunnlag for å si at agonist-antagonist superset er en tidseffektiv måte å trene styrke på, som kan være fordelaktig for friske voksne. Det er behov for flere og større studier som strekker seg over lengre perioder for å kunne gi mer presise resultater, men mye tyder på at bruken av superset er en effektiv metode for både tidsbruk og volum.

Abstract

Purpose: The health benefits of exercising is commonly known. Although people are aware of the benefits, prioritizing training is often difficult because of time-consumption. This study investigates the effects of agonist-antagonist supersets on time-efficiency, volume, rating of perceived exertion, hypertrophy and strength. **Methods:** Studies were found through PubMed, Oria and Google scholar between 20.2.2021 and 10.03.2021. The participants had to be between 18-40 years old, and considered as healthy adults. The studies had to be randomized studies conducted with one superset group and one traditional group. **Results:** 8 studies were included in this literature search. The studies show that one can achieve the same, or higher volume in a shorter or the same amount of time as traditional training, without affecting the rating of perceived exertion. There were few findings on strength and hypertrophy.

Conclusion: Based on the included studies it is reasonable to say that agonist-antagonist supersets is a time efficient method. A method that could be beneficial for healthy adults. There is a need for more and larger studies conducted over a longer period of time, although a lot indicates that supersets are an efficient method for both time consumption and volume.

Keywords: Time-efficiency⬥agonist-antagonist⬥Superset⬥Resistance training⬥volume⬥RPE⬥hypertrophy⬥strength

1. Introduction

Resistance training was previously regarded as something athletes, bodybuilders and powerlifters did to improve their performance in sport exercises. Today, resistance training is well known as one of the most effective methods to increase muscle hypertrophy and muscle strength (Schoenfeld et.al., 2010). Not to mention that it has shown to give other health benefits as well. Studies have shown that by utilizing resistance training, one can reverse muscle loss, reduce body fat, facilitate physical function, improve metabolic health, improve cardiovascular health, and increase bone mineral density (Westcott, 2012). Resistance training can provide improvements in mental health, self-esteem, mood, perceived strength and improve human's physical self-perception in obese or overweight individuals (Goldfield, 2015). How much resistance training and volume that is needed to achieve notable results is of interest for everyone who exercises. The American College of Sports Medicine (ACSM) has defined exercise guidelines, where recommendations for traditional strength training are defined for healthy adults. ACSM recommendations for healthy adults suggest that strength training should be performed at a minimum of two days each week, with 8-12 repetitions of 8-10 different exercises that target all major muscle groups. The recommendation for training frequency is 2-3 days a week for novice training, 3-4 days a week for intermediate training, and 4-5 days a week for advanced training («Progression Models in Resistance Training for Healthy Adults», 2009).

One of the major challenges for a lot of people regarding resistance training is consistency and prioritizing time for workouts. Therefore, it is beneficial for a lot of people that the resistance training is time efficient. Utilizing supersets is one method to make resistance training more time efficient. This method combines two different exercises, so that they are completed consecutively, with little to no rest between them. This study includes agonist-antagonist supersets, which is characterized by using agonist muscles followed using antagonist muscles. Utilizing agonist-antagonist supersets is suggested to be a more time efficient method than traditional training, due to a shorter time frame, or a higher volume. Volume can be defined as the number of repetitions multiplied by the number of sets. Volume can also be defined as the total weight lifted in kilograms during the session. It is suggested that a higher volume may lead to greater hypertrophic increase and muscle strength (Marx et.al., 2001). A workout can be considered time efficient when the volume is equal between a superset protocol and a traditional protocol, but the time is shorter. This method can also be considered time efficient if the volume is higher, but the time spent to complete the session is

equal for both methods. Using agonist-antagonist supersets is suggested to facilitate a higher volume in a shorter time than traditional training due to the alternation between two exercises before implementing rest, while traditional training implements rest between each exercise.

Understanding how much volume and the total time used affects the rate of perceived exertion and how it compromises the potential for muscle hypertrophy and muscular strength utilizing agonist-antagonist supersets could be beneficial to achieve optimal results. Perceived exertion is how exerted one person feels after a session, and is usually characterized by a scale, rating from zero to ten. Resistance training that involves pairing of exercises for agonist-antagonist muscle groups may be a time efficient alternative for healthy adults during everyday life.

The purpose of this study is therefore to investigate how the use of agonist-antagonist supersets affects time-efficiency, volume, rating of perceived exertion and hypertrophy and strength outcomes compared with traditional strength training.

2. Methods

2.1. Literature search

The National Library of Medicine (Pubmed), Google scholar and Oria search engines were used to find studies that investigate the effects of agonist-antagonist supersets compared to traditional strength training. In Pubmed, advanced search was used to find relevant studies. The Advanced search function uses keywords combinations to find relevant studies. In this search, the following keyword combinations that was used: ('Strength training' OR 'Resistance training' OR 'Time-Efficiency'') AND ('Supersets' OR 'Paired sets' OR 'Antagonist Agonist' OR 'Hypertrophy' OR 'RPE' OR 'rate of perceived exertion' OR 'Volume'). In both Oria search engine and google scholar no advanced search engine was used. In all the search engines, manual searches were conducted. In these searches "effects of agonist-antagonist resistance training" and similar terms were searched to find studies that contained the right content. Further, reference lists of relevant studies were reviewed.

2.2. Inclusion and exclusion criteria

Research studies that investigated the effects of agonist-antagonist supersets compared to the effects of traditional strength training were included in this literature search. The first screening of the studies that were identified was based on the title, abstract and the overall content of the study. The studies that were still in consideration were read and selected based

on the content, and whether they contained the outcomes we were interested in investigating. These outcomes were time-efficiency, agonist-antagonist superset/paired set, resistance training, volume, rating of perceived exertion, hypertrophy and strength. Restrictions regarding the time of publishing were set to be no older than 2010. Another inclusion criteria was that the found literature was to include participants that were considered as healthy adults, aged between 18-40 years old.

3. Results

The outcomes that were investigated were extracted from 8 studies. In these studies, there were a total of 117 participants, where 12 of them were women. All of the studies had protocols that compared traditional strength training to superset training. The following three tables are based on differences in the study design and outcomes.

Table 1: Randomized controlled trials. Characteristics and outcomes

Study	Study duration (weeks), subjects (n). Age (years, mean and standard deviation)	Protocol	Outcomes
Fink et al., 2020	8 weeks n=25 19.2 ± 1.8 years	**Traditional protocol:** 3 sets of bicep curls, 3 sets of overhead triceps extension, 1 min rest between sets. **Superset protocol:** 3 sets of bicep curls alternated with 3 sets of overhead triceps extensions, 1 min rest between sets.	**Average number of reps for TS group:** Biceps curl: 40.2, triceps extension: 25.4. **Average number of reps for SS group:** Biceps curl; 45.9, triceps extension: 22.2. No difference between groups on RPE measured by the revised category-ratio scale (0-10) **Average time to complete protocol:** TP; 8min. and 18sec. including five 1min. breaks. SS; 5min. and 24sec. including two 1min. breaks 2 minutes and 54 seconds difference between groups. **Changes in biceps CSA (%):** TP: Pre: 2.2, Post: 2.5. SS; Pre: 2.1, Post: 2.3 **Changes in triceps CSA (%):** TP: Pre: 5.6, Post: 6.0. SS; Pre: 5.2, Post: 5.4 **Changes in 1RM on close grip bench press:** TP: Pre: 53.1kg, Post: 56.7kg. SS: Pre: 45.2kg, Post: 47.5kg **Changes in 1RM barbell curl:** TP: Pre: 29.8kg, Post: 30.5kg SS: Pre: 26.2kg, Post: 27.3kg
Robbins et al., 2010	8 weeks n=16 23.6 ± 1.8 years	**Traditional Protocol:** 3 sets of bench pull followed by 3 sets of bench press, 2 min rest between sets. **Superset protocol:** 3 sets of bench pull alternated with 3 sets of bench press, 4 min rest between like sets, but less rest between sets than in traditional protocol	**Total volume for TP:** Bench pull: 738.1kg. Bench press: 731.3kg **Total volume for SS:** Bench pull: 895.4kg. Bench press: 930.4kg **Total volume difference:** TP vs. SS; 356.4kg **Kgs/min bench press:** TP; 73.1. SS; 93.0 **Kgs/min bench pull:** TP; 73.8. SS; 89.5 **Time:** Both groups completed the session in 10 minutes as described in the protocol.

PS= paired sets, TP= traditional protocol, CSA= cross sectional area, RM= repetition maximum

Table 2: Crossover studies. Characteristics and outcomes.

Study	Study duration(weeks), subjects (n), age (years, mean + SD)	Protocol	Outcomes
Paz et al., 2017	1.5 weeks n=12 22.4 ± 1.1 years	**Traditional protocol** 3 sets of bench press followed by 3 sets of wide grip seated row with a 10RM load, 2 min rest between sets. **Superset protocol** 3 sets of bench press and 3 sets of wide grip seated rows performed in an alternating manner with 2min rest between unlike sets	**Total volume for TP vs. SS on bench press:** TP: 1188.4 ± 115kg SS: 1328 ± 27.5kg **Total volume for TP vs. SS on seated rows:** TP: 960.5 ± 100.1kg SS: 1249.4 ± 135.5kg Lower volume for bench press on TP vs. SS on sets 2 and 3. Higher volume in SS group compared to TP group even though the SS group had less rest than TP group (4 min vs. 10 min).
De Freitas Maia et al., 2015	1 week n=15 24.2 ± 11.1	**2 min protocol** One set of bench press immediately followed by one set of seated rows with a 8RM load. Three supersets in total. 2min rest between sets. **4min protocol** one set of bench press immediately followed by one set of seated rows with a 8RM load. Three supersets in total. 4 min rest between sets,	**Total volume 2minute protocol:** Bench press: 22.9 ± 1.3 repetitions Seated row: 25.4 ± 1.7 repetitions **Total volume for 4minute protocol:** Bench press: 22.6 ± 0.8 repetition. Seated row: 25.1 ± 1.3 repetitions **Total time for 2min protocol:** 12 minutes including sets and pauses. **Total time for 4min protocol:** 22 minutes including sets and pauses. No difference in RPE

SS = supersets, TP = traditional protocol, RM = repetition maximum, RPE = rating of perceived exertion

Table 3: Crossover studies with time equated between groups. Characteristics and outcomes.

Study	Study duration(weeks), subjects (n), age (years, mean + SD)	Protocol	Outcomes
Miranda et al., 2020	2 weeks n=12 25.7 ± 4.7 years	**Traditional protocol** 3 x 10reps at 85% of 10RM, seated rows and barbell bench press, 2min rest between sets. **Superset protocol** 3 x 10 reps at 85% of 10RM alternating between seated rows and barbell bench press, 2min rest between sets.	**Average RPE (OMNI-RES scale) for seated row:** TP: 4.7 SS: 5 **Average RPE (OMNI-RES scale) for bench press:** TP: 6 SS: 6
Weakley et al., 2020	4 weeks n=10 20.9 ± 0.6 years	**Traditional protocol** One set of barbell bench press, 5min rest, then 3 following sets of barbell bench press with 2min rest between sets. **Supersets group** One set of barbell bench press, 5min rest, then 3 sets alternating between bent over rows and barbell bench press, 2min rest between sets. All exercises are loaded with 65% of 3RM. 3 x 10 reps on all exercises, 2sec eccentric action and concentric action as "forceful and powerful as possible"	Greater mean RPE measurements in all three SS protocols compared to traditional protocol. **Mean RPE (BORG scale) measurements:** TP: 2.9 SS: 4.0 Difference between protocols; 1.1
Antunes et al., 2018	1 week n=12 24.0 ± 3.3 years	**Traditional protocol** 3 sets of leg extensions at 60bmp, 10RM load. **SS fast protocol** 3 sets of leg extensions preceded by one set of leg curls at 90bpm, 10RM load. **SS slow protocol** Same as fast protocol, except leg curls were performed at 40bpm, 10RM load.	**Mean volume for all sets for each protocol:** TP: 362.6kg SS fast: 457.6kg SS slow: 454.1kg Higher volume for SS fast group vs. TP group even though the cadence is faster. Lower volume in TP vs. both SS protocols. Higher muscle activation in TP vs. SS
Maia et al., 2014	3 weeks n=15 22.5 ± 1.9 years	**Traditional protocol** 1 set of knee extension on a 10RM load until concentric failure. **Supersets protocols** Alternating between knee flexion and knee extension with either 15sec, 1min, 3min or 5min rest between sets, also on a 10RM load.	**Mean volume for traditional protocol vs. superset protocol (Mean + SD)** TP: 10.2 ± 0.4 reps SSMR: 13.5 ± 1.3 reps P30: 12.7 ± 1.2 reps Lower volume in TP vs. SSMR and P30. Higher EMG activity in rectus femoris for minimal rest group vs. TP, 3min and 5min group.

SS = supersets, TP = traditional protocol, RM = repetition maximum, RPE = rating of perceived exertion SSMR=supersets with minimum allowed rest (<15 seconds), bpm = beats per minute, EMG = electromyography, SD= standard deviation

3.1 Findings

3.1.1 Time-efficiency and volume

3 out of 8 studies found that using superset is more time efficient, due to the protocol, compared to traditional strength training. Fink et al., (2020), Maia et al., (2015) and Paz et al., (2017) found that the superset protocols were time efficient with either more volume, or the same volume, in a shorter amount of time. Robbins et al., (2010) found that the superset protocols were time efficient with a higher volume using the same amount of time as the traditional protocol. Antunes et al., (2018), and Maia et al., (2014) had protocols that made the time-efficiency between the superset group and traditional group difficult to compare, due to a different number of exercises in the protocols and cannot be compared in the same way as the other studies included. Weakley et al., (2020) and Miranda et al., (2020) had protocols with the volume pre-determined.

Randomized controlled trials

Fink et al., (2020) found an average number of 68.1 repetitions on biceps curls and triceps extension combined, while the traditional group did an average number of 65.6 repetitions. The total difference between the groups is 3.7% more volume for the superset group. This shows that no significant difference in total training volume was observed between groups for either exercise ($P > 0.05$). The study showed a 2 minutes and 54 seconds shorter session for the superset group, compared to the traditional group. The superset group performed an average of 5.7 more reps on biceps curls, and 3.2 less reps on triceps extension. This makes the superset protocol time efficient compared to the traditional protocol, where the participants achieve a similar amount of volume within a shorter time.

Robbins et al., (2010) found that the superset group lifted 912.9kg on average on bench pull and bench press combined, while the traditional group did an average of 739.7kg. This equals a total difference of 356.4kg between the groups, which makes a total of 19 % higher volume for the superset group. The superset protocol is time efficient as it permits a higher volume to be performed within the same amount of time.

Time-efficiency with a shorter time and a higher volume

Paz et al., (2017) found that the superset group achieved a higher volume than the traditional group, even with a total of just 4 minutes rest, while the traditional group had 10 minutes rest. There is a 17% higher volume in the superset protocol, with 6 minutes shorter rest. Maia et al., (2015) found that one superset protocol lasted 12 minutes, and the other superset protocol lasted 22 minutes including sets and pauses. This shows a total of 10 minutes difference between the protocols. The 2-minute superset protocol had an average of 0.7 more reps on bench press and 0.3 more reps on seated row, compared to the 4-minute superset protocol, which is a total of 1.2% higher volume in a shorter amount of time.

The mean time saved by using superset in these three studies, Fink et al., (2020), Paz et al., (2017), and Maia et al., (2015), is 6 minutes and 18 seconds. Whereas the mean time used for the traditional protocols were 13 minutes and 24 seconds, and the mean time used for the superset protocol was 7 minutes and 6 seconds, which equals a mean of 47% less time.

Time-efficiency with equal time and a higher volume

Robbins et al. (2010) found higher volume for the superset group in the same amount of time and is therefore considered time efficient.

Incomparable protocols for time-efficiency

Weakley et al., (2020) and Miranda et al., (2020) had all predetermined time due to protocols. Weakley et al., (2020) and Miranda et al., (2020) also had volume predetermined, and can therefore not be considered time efficient. The studies of Antunes et al., (2018), and Maia et al., (2014) had protocols that made the time-efficiency between the superset group and traditional group difficult to compare, due to a different number of exercises between protocols.

Antunes et al., (2018) showed that both superset protocols had higher volume than the traditional protocol. SS-fast had 20.8% more volume and SS-slow had 20.1% more volume. The study found that the mean volume lifted for the SS-fast protocol was 457.6 kg, 451.1 kg for SS-slow and 362,6kg for the traditional protocol. The volume was only measured in knee extensions, due to protocol. This shows that both SS-fast and SS-slow are more efficient, with more volume conducted.

Maia et al., (2014) investigated the effects of different rest intervals in agonist-antagonist supersets. The minimal rest superset protocol showed an average of 13.5 reps, and P30

protocol showed an average of 12.7 reps. The results were only extracted from the knee extension tests, although the superset group did both knee extension and knee flexion. This shows that the minimal rest superset protocol is the most efficient, both in time used and reps conducted. This equals a 24.4% higher volume in the minimal rest superset protocol compared to the traditional protocol.

3.1.2 Rating of perceived exertion

Four out of eight studies investigated the differences in Rating of perceived exertion between the superset groups and the traditional groups. OMNI-Resistance Exercise Scale (OMNI-RES), The Borg Scale and the Revised category-ratio-scale. The perceived exertion is measured from 0-10, where 0 is the least fatigue, and 10 is completely exhausted (Robertson et al., n.d). Weakley et al., (2020) found a difference in RPE between protocols, whereas the remaining three studies showed no difference. Miranda et al., (2020) found an average score of 4.7 for the traditional group in seated row and 5 for superset using OMNI-RES scale. The average rating of perceived exertion on bench press was 6 in both traditional and superset groups. This shows an increase in rating of perceived exertion throughout both protocols, but no significant difference between them.

Maia et al., (2015) found no statistical difference between the superset group and the traditional group on the rating of perceived exertion, using the OMNI-RES-scale. Fink et al., (2020) found no difference in rating of perceived exertion between the two protocols (P>0.05). Weakley et al., (2020) showed an almost certain greater rating of perceived exertion in the superset protocol compared to the traditional protocol. The traditional protocol had a mean of 2.9 on rating of perceived exertion while the superset protocol showed a higher mean with 4.0.

3.1.3 Strength and hypertrophy

Only one study out of the eight assessed strength and hypertrophy. Fink et al. (2020) did investigate the increase of 1 repetition maximum between traditional and superset protocols in both bench press and barbell curl. The mean improvements in the traditional group of 1RM was 3.6kg on bench press, and 0.7kg on the barbell curl. As for the superset group, the mean difference was 2.3kg on the bench press, and 1.1kg on the barbell curl. The findings showed that the 1 repetition maximum bench press significantly increased (P<0.05) in the traditional group. The superset group did not reach statistical significance (P>0.05) on the bench press.

In the barbell curl, the two protocols did not reach statistical significance (P>0.05). The study did not observe any between-group differences in either outcome ($P > 0.05$).

Fink et al., (2020) investigated the differences in hypertrophy outcomes between traditional and superset protocol, through assessing muscle cross sectional area before and after the training period and found that the mean difference in cross sectional area for traditional group was 0.3% in the biceps, and 0.5% on the triceps. For the superset group, the mean cross sectional area difference was 0.2% in biceps, and 0.2% in the triceps. This shows that both protocols had a significant CSA increase in both the biceps and triceps (P<0.05), without any differences between the two groups (P>0.05).

4.0 Discussion

The purpose of this study was to investigate how the use of agonist-antagonist supersets would affect time-efficiency, total volume, rating of perceived exertion and hypertrophy and strength outcomes, compared to traditional strength training. The main findings of this study were that agonist-antagonist supersets are a time efficient method to conduct resistance training, where one can get in the same amount of volume, or more, in a shorter session, or more volume in the same amount of time as traditional resistance training. The findings in this study show that the use of agonist-antagonist supersets did not increase the rating of perceived exertion. Only one study investigated hypertrophy and strength outcomes and found no differences between the superset group and the traditional group.

4.1 Time-efficiency

Fink et al., (2020), Maia et al., (2015) and Paz et al., (2017) showed that the utilization of supersets is a time efficient way of training and showed that the mean time to complete the respective protocols was 6 minutes and 18 seconds less for the superset protocol, compared with the traditional protocol, this equals 47% less time. Why the three studies showed this result is partially due to differences between protocols. The predetermined rest time did affect the time to complete the protocols. The volume was higher or relatively similar, but in less time. A higher volume in the same amount of time can also be considered time efficient, as shown by Robbins et al., (2010). Fink et al., (2020), Maia et al., (2015) and Paz et al., (2017) show a higher volume with lower rest between sets, in contrast to Robbins et al., (2020), who show a higher volume with longer rest between the sets working the same muscle group. It is

difficult to point out all the underlying factors contributing to these results, but the load used in Robbins et al., (2020) together with the long breaks in between sets could be one of the reasons. A study done by Schoenfeld et al., (2016) provides evidence that longer rest periods promote greater increases in muscle strength and hypertrophy and showed that the total aggregate load volume over the 8 weeks was greater on an absolute basis for long rest time, 3 minutes, compared to short rest time, 1 minute.

It is known that everyday life is getting more and more hectic, and some people struggle with prioritizing time to work out. Therefore, a time efficient method to conduct resistance training is of importance. A systematic review by Krzysztofik et al., (2019) investigated the maximizing of muscle hypertrophy and found that supersets were a more time efficient way to execute resistance training, than traditional resistance training. As this literature search shows, and which is supported by Krzysztofik et al., (2019), a lot of time can be saved in just two exercises. By utilizing agonist-antagonist supersets one can achieve more, or the same amount of volume in a shorter session, or more volume in the same amount of time. It is important to point out that these studies used between two to four exercises within the whole session, whereas most people usually perform more exercises within a training session. The time that can be saved on an entire session could therefore be considerably greater. This shows that by utilizing supersets in everyday life, healthy adults can decrease the time spent working out.

4.2 Volume

Fink et al., (2020), Paz et al., (2017) and Maia et al., (2015) showed a higher volume in a shorter time, while Robbins et al., (2010) found time-efficiency through a higher volume in the same amount of time as the traditional protocol. The studies of Antunes et al., (2018), and Maia et al., (2014), had protocols that made the time-efficiency between the superset group and traditional group difficult to compare, but still showed a higher volume for the superset group. Krzysztofik et al., (2019) indicates that higher volume of effort is warranted for maximizing muscle growth response in a diverse population, where volume of resistance training is the key element of adaptation in terms of muscle hypertrophy.

The volume for Fink et al., (2020) is calculated from the average repetitions completed in all sets, while for Robbins et al., (2010) the volume is calculated from the average kilos lifted in all sets, due to the different protocols. The volume difference between the two studies could be affected by different variables, such as the different protocol for the resting period. In

Robbins et al., (2020) the sets were done by a 4RM load and 4 minutes rest in between each set. This long rest time could affect the total volume, where it is known that when doing sets with heavy weight, long rest time is necessary to achieve a higher volume (Schoenfeld et al., 2016). In contrast to Fink et al., (2020) where the participants performed 50% of 1RM in both protocols, targeting a repetition amount of 30-40 repetitions, with a rest time of 60 seconds between sets for both superset and traditional group.

All crossover studies showed a higher volume for the superset group compared to the traditional group except for Miranda et al., (2020) and Weakley et al., (2020) where the repetitions, sets and weight lifted were predetermined.

The studies included in this literature search indicates that the use of supersets leads to a higher volume. This could among other things be due to the fact that when using the agonist muscles, the antagonist muscles are activated and may trigger different muscular responses. This could be shown in Maia et al., (2014) where the participants in the superset group did knee flexion before knee extension and still had a 24.4% higher volume. The same could affect the results in Antunes et al., (2018), as the two superset protocols showed 20.1% and 20.8% more volume in the researched exercise versus the traditional group. The rest-time, load and what exercises are utilized will affect the total volume.

4.3 Rate of perceived exertion

Four out of eight studies measured the rate of perceived exertion. Three out of four studies show that there is no significant difference on the rating of perceived exertion between superset and traditional resistance training, which indicates that it could be beneficial in relation to training more time efficiently. This effect can also be seen in the study by Lins-Filho et al., (2012), which investigated the effect of exercise intensity on the rating of perceived exertion during a multiple-set resistance exercise session. Although this study did not investigate the effect of supersets, it studied the effect of the rating of perceived exertion on different exercises, and their findings showed that it did not get influenced by the previous exercise. It therefore supports the findings in the other studies included, which showed no difference in the rate of perceived exertion. It is important to point out that the participants in this literature search were healthy adults, where most of them had some previous experience with resistance training. Therefore, it is difficult to generalize these results for the overall population, which lack the equivalent experience.

The findings made by Lins-Filho et al., (2012) showed that resistance training performed over 70% of 1RM often increases the rating of perceived exertion. Weakley et al., (2020) found that the participants performing resistance training with 65% of their 3RM showed differences in rating of perceived exertion between superset and traditional protocol. This could be due to the exercise performed, where the participants did barbell bench press and bent over rows, which are compound movements and target large muscle groups. Miranda et al., (2020) and Maia et al., (2015) had protocols with resistance between 80-85% of 1RM showed no difference between protocols. This indicates that higher volume may lead to an increase in rating of perceived exertion, but no difference between the usage of supersets compared to a traditional protocol. The participants in Fink et al., (2020) performed biceps curls and triceps extension and found no difference in rating of perceived exertion between the protocols. This could be due to the single-joint movement that targets smaller muscle groups.

It is important to point out that these studies used between two to four exercises within the whole session, whereas most people usually utilize more exercises within a training session, which could affect the rating of perceived exertion more.

4.4 Strength and hypertrophy

Only one study in this literature search assessed the effect on strength and hypertrophy through agonist-antagonist supersets. Fink et al., (2020) measured changes in both 1RM on the bench press and the barbell curl. 1RM was assessed on both exercises one week before and one week after the training period. Fink et al., (2020) also measured hypertrophy one week before the training period, and 72-96 hours after the completed training period. The measurements were done by mapping the muscle cross-sectional area on the biceps brachii and triceps brachii. There was a statistically significant increase in 1 repetition maximum on bench press for the traditional protocol. On the other hand, there were no statistically significant results on bench press for the superset group, nor for either of the protocols on biceps curls. The study found differences in cross sectional areas on both biceps brachii and triceps but found no differences between protocols. Even though analysis of the results suggest that the findings are statistically significant, the study did not observe any between-group differences in either outcome ($P > 0.05$).

However, the superset group performed three sets of two exercises, with a resistance equating 50-60% of 1RM, with a total variation between 30-40 repetitions, 3 times per week for a

period of 8 weeks, which is lower than ACSM's recommendations of 60-70% of 1RM for novice and >80% for experienced lifters to increase strength («Progression Models in Resistance Training for Healthy Adults», 2009).

Findings on hypertrophy by Schoenfeld et al., (2019) suggests that a higher volume leads to greater hypertrophic increase. In this literature search, six out of eight studies found a higher volume in the superset protocol, compared to the traditional protocol. These results may indicate that utilizing agonist-antagonist supersets could be beneficial if the goal is a hypertrophic increase.

The sample size in this study may be too small to give accurate and applicable results.

4.5 Strength and weakness of the study

The fact that the literature search is not systematically conducted or analyzed weakens the results. The quality of the studies that is included, and the risk of bias is not reviewed. There are several other aspects of this study that could affect the results. There are only 8 studies included, and a total of 117 participants, with only 12 women, this affects the generalizability of the study. To include an equal number of men and women would strengthen the generalizability. The studies included healthy adults, and most of them had some previous experience with resistance training. Some of the studies are conducted differently and have different protocols, where three studies shorten the rest-time, while five studies used the same rest-time for the superset group and the traditional group. Therefore, there are fewer participants overall per sub-question. A bigger selection would give results for a higher generalizability (Pripp et al., 2018). Among all the studies, there were only two randomized controlled trials. Including more randomized controlled trials would strengthen the results, as this study-design is considered to be the gold standard when it comes to studying effects of measures (Helsebiblioteket, 2016).

4.6 Practical implications and future research

Time efficient resistance training can be beneficial for the general population. It enables the individuals to find time to work out, during a somewhat hectic everyday life. Because of the general health benefits of resistance training, time efficient strength training programs would likely provide for a substantial effect on the health of the general population.

Fink et al., (2020) found improvements in the 1RM in bench press and barbell curl, and an increased cross-sectional area in both bicep and triceps for both protocols, but there is a need for more and larger studies on this topic to better understand the mechanisms and outcomes for the long-term effects of using agonist-antagonist supersets. It is of interest to investigate the outcome of a higher volume in the superset protocols over a longer period of time, and how this will affect the hypertrophy and strength outcomes. If healthy adults could get the same hypertrophy and strength results, with no greater perceived exertion, while saving time using agonist-antagonist supersets, it would benefit a lot of people.

5. Conclusion

After the conducted literature search, it is reasonable to say that agonist-antagonist supersets are a time efficient way to conduct strength training. The literature search also indicates that one can get in the same amount of volume in a shorter time, or a higher volume within the same time using supersets compared to traditional training. This can be beneficial for healthy adults and people in general that are struggling to make time for resistance training. How this affects the rating of perceived exertion is still not clear, but the studies indicate that it does not give a higher rating of perceived exertion. How the use of agonist-antagonist supersets affects the outcomes for hypertrophy and strength is still not clear and needs further investigation. There is a need for more and larger studies conducted over a longer period of time.

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