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Original Article

Effect of weight training and motor skills on muscle strength: A factorial experimental design

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Abstract:
Problem Statement and Purpose. Previous studies have discussed various methods of weight training to increase muscle strength. However, very limited studies involve motor skills to obtain better results. This study aims to analyze group differences in weight training by considering the level of motor skills on the results of leg muscle strength. The group in weight training consisted of the circuit and conventional systems, while motor skills were classified into high and low. ***Methods.*** This study used a two-way factorial experimental design involving 36 young men aged 20.03 ± 0.51 years. Weight training was given ± 6 weeks with the frequency of 3 times per week. The intensity and training load addition was 75% of 10 RM. Weight training with a circuit system consisted of 9 stations, 10 repetitions, 3 sets (1 set equals 9 completed stations). The rest between stations was 20 seconds, and between sets was 2 minutes. In conventional weight training, each exercise was performed in 1 place, 10 repetitions, and 3 sets in the same place. The rest between sets was 2 minutes. Then it moved to the next exercise in the same way. Data on motor skills and leg muscle strength were obtained from the Barrow motor ability and leg dynamometer tests. Then, it was analyzed using a two-way factorial ANOVA test and Tukey's further test. ***Results.*** These findings indicated that the results of leg muscle strength given weight training with a circuit system were better than the conventional one ($P < 0.05$), with an average of 74.56 > 71.72. The research also found an interaction between weight training and motor skills on leg muscle strength ($P < 0.05$). Weight training with a circuit system was better than conventional for high motor skills ($P < 0.05$), with an average of 78.22 > 70.44. Weight training with circuit and conventional systems did not differ significantly for low motor skills ($P > 0.05$), with an average of 70.89 < 73.00. ***Conclusions.*** High motor skills are more suitable for weight training with a circuit system, while low motor skills can be given both forms of training. However, the results will be better if given conventionally. Therefore, instructors, practitioners, and athletes must consider motor skills in weight training to produce optimal leg muscle strength.
Keywords: weight training, circuit, conventional, motor skills, leg muscle strength.

Introduction

Muscular strength is an important component of fitness. Research shows that it can improve health and functional ability (Newman et al., 2006), minimize injury (Balshaw et al., 2017), and avoid chronic illness (Cheema et al., 2014). Muscle strength is typically developedby combining several morphological and neural factors (Suchomel et al., 2018). However, the enhancement mechanism can be associated withmultiple factors, ranging from innate strength (Balshaw et al., 2017), training situation (Buckner et al., 2017), and heredities (Yang et al., 2003).

In this regard, researchers often perceive resistance training as the main exercise to increase muscle strength (Blocquiaux et al., 2020; Feriche et al., 2017; Lasevicius et al., 2018; Lattari et al., 2017; Martins et al., 2015) or hypertrophy (Feriche et al., 2017; Lasevicius et al., 2018; Mario et al., 2022a; Mario et al., 2022b; Schoenfeld et al., 2015a). However, resistance training must consider several variables such as volume, sequence, reps, sets, movement tempo, rest time between sets, and type of exercise (Ralston et al., 2018). Among them, exercise volume and intensity have received the most attention (Ralston et al., 2017; Schoenfeld et al., 2017; Schoenfeld et al., 2014a). In comparison, the potential for training frequency to affect increased muscle strength is negligible (Grgic et al., 2018). The American College of Sports Medicine recommends that beginners and intermediate categories train each muscle group two to three times per week (upper and lower body). Meanwhile, more trained individuals are advised to practice regularly one to three muscle groups per training session (American College of Sports Medicine, 2009). In addition, some researchers are trying to understand the extent to which the frequency of resistance training can affect muscle strength (Fernández-lezaun et al., 2017; Padilha et al., 2015; Schoenfeld et al., 2015b; Silva et al., 2017; Thomas & Burns, 2016). A few of these studies investigated trained individuals (Schoenfeld et al., 2015b; Thomas & Burns, 2016) and older adults (Fernández-

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lezaun et al., 2017; Padilha et al., 2015; Silva et al., 2017). However, research that investigates the use of resistance training methods such as circuits is rare.

The popularity of circuit resistance training emerged in the early eighties as it showed a positive effect on muscle strength (American College of Sports Medicine, 2009; Brentano et al., 2008). This exercise replaced high-volume resistance with very short rest periods between exercises (Waller et al., 2011). Besideschoosing the right training method, practitioners need to consider the characteristics of each individual before providing training programs (Suchomel et al., 2018).This includes the level of motor skills in resistance training that is often neglected. In fact, muscle strength is vital for motor performance (Behringer et al., 2011), so it needs to be considered. As mentioned earlier, several studies have examined resistance circuit training and its methods. These studies are influential as they allow the researchers to compare them. However, there are still limited studies involving motor skills. Of these few studies, one examineshow circuit resistance training can affectthe health of elderly populations (Romero-arenas et al., 2013). To respond to this gap, this study examines the effectiveness of the training program for circuit resistance. The study also compares the training to traditional strength training that targets muscle strength, muscle size, body composition, and cardiovascular fitness. Aerobic circuit resistance training improves aerobic fitness and muscle strength (Myers et al., 2015). This study compares a circuit-based whole-body resistance training group and a traditional resistance training program combined with aerobic exercise in sedentary young women. Then, the reducing effect of progressive circuit resistance training on inflammatory biomarkers and cardiometabolic risk factors in young obese men (Kolahdouzi et al., 2018).

Further, other studies investigate resistance training and the methods that can be performed to obtain optimal muscle results. The relationship between resistance training, muscle strength, and hypertrophy (Schoenfeld et al., 2015a). This study observed resistance training using high versus low loads in trained men. Study of resistance training with single versus multi-joint exercises (Paoli et al., 2017). This study used single-joint and multi-joint exercises as treatment groups to compare the effects of equivalent volume resistance training. Study of comparing acute and subacute responses to hormonal profiles and metabolic parameters of two methods of strength training (Paunksnis et al., 2017). This study involved the elderly with two training methods with constant intensity and variable intensity. Further, Martins et al. (2015) dicussed short-term elastic resistance training's effects on strength and muscular mass. They examined short-term elastic resistance training for muscle mass and strength in older adults who rarely do exercise. Tempo of movement in weight training to produce hypertrophy was also investigated (Marioet al., 2022a). This study involved untrained young men with slow-motion treatments to produce hypertrophy. Then, how high protein foods in weight training can produce hypertrophy (Mario et al., 2022b). It aims to find alternatives in obtaining hypertrophy in weight training by consuming soy milk, egg whites, and tofu. To the best of our knowledge, very limited studies investigate circuit system weight training based on motor skill level for leg muscle strength.

Therefore, this study aims to analyze group differences in weight training by considering the level of motor skills on the results of leg muscle strength. Weight training consists of the circuit and conventional systems, while motor skills are classified into high and low. These findings are significant for fitness instructors, practitioners, and athletes in increasing leg muscle strength. They provide information that should be taken into account when involving motor skills in weight training.

Materials & Methods

Study design

This study is an experimental design with a two-way factorial ANOVA. Weight training (A) consisted of two forms of treatment, namely, the circuit system (A1) and conventional (A2). Meanwhile, motor skills (B) comprised high (B1) and low (B2) motor skills. As presented in Table 1, the study involves 4 treatment groups, weight training with a circuit system for high and low motor skills (A1B1 and A1B2). Then, conventional weight training for high and low motor skills (A2B1 and A2B2).

Table 1. A two-way factorial ANOVA design

Motor skills (B)	**Weight training (A)**	
	Circuit system (A1)	**Conventional (A2)**
High (B1)	**A1B1**	**A2B1**
Low (B2)	**A1B2**	**A2B2**
Total	**A1**	**A2**

Note- Dependent variable: Leg muscle strength.

Participant

A total of 36 young men participated in this study, who were randomly recruited. These participants were students who took a physical conditioning course at the sports coaching departmentat a state university in Indonesia. The participants were beginners in weight training. They have declared to comply with the rules during treatment and participate voluntarily through a written agreement. The participants were aged 20.03 ± 0.51 years, weight was 65.78 ± 2.72 kg, height was 169.33 ± 2.37 cm, and BMI was 22.94 ± 1.05.

Procedure

Distribution of treatment groups

Motor skills tests were conducted by dividing the groups using the two-way factorial ANOVA design. This test was carried out before weight training was treated with circuits and conventional systems. The test initially consisted of 68 participants and motor skill scores were ordered from maximum to minimum. The upper (27%, n = 18) was classified as having high motor skills, and the lower (27%, n = 18) was classified as having low motor skills. The 27% division for the upper and lower sections was intended so that the participants' motor skills differed significantly (high and low). Then, the division of groups for the treatment of weight training with circuit and conventional systems was carried out by lottery based on groups of high and low motor skill levels. As presented in Figure 1 and Table 2, there are 4 treatment groups, each of which has 9 participants.

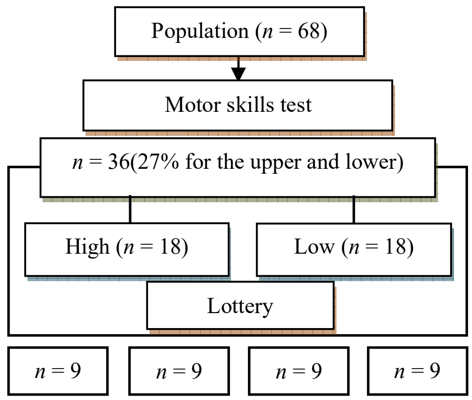


Figure 1. Procedure for division of treatment groups

Table 2. The number of participants for each treatment group

Motor skills (B)	Weight training (A)				Total (n)
	Circuit system (A1)	*n*	Conventional (A2)	*n*	
High (B1)	A1B1	9	A2B1	9	18
Low (B2)	A1B2	9	A2B2	9	18
Total	A1	18	A2	18	36

Treatment for weight training

This study used weight training with conventional and circuit systems that focused on the leg muscles. Weight training ranfor ± 6 weeks, 3 times per week. This exercise began with a 10-minute warm-up, followed by core exercises (circuit and conventional systems), and a 10-minute cool down. In the first week (first meeting), the initial load for each sample was 75% of 10 RM. The training load was increased for three consecutive weeks. With regard to the initial load and its addition, if the repetition of the load for each sample was more than 10 times, then a new 10 RM was sought again by changing the load under the principles of overload, progressive, and individualization. In the fourth week, the training load was lowered and equalized in the second week (unloading). This was so that the body could recover to gather energy. The process of changing the load (adding load) in the fifth and sixth weeks was the same as in the second and third weeks. Then, at the end of the sixth week (after treatment) the leg muscle strength of each sample was measured. Weight training movements for leg muscles consisted of good morning exercises, lunges, leg raise exercises, leg extensions, leg curl exercises, squats, Jefferson lifts, hack squats, and leg squats.

Circuit system weight training consisted of 9 stations according to the weight training movements for leg muscles. Weight training was done with 75% of 10 RM, 10 reps, and 3 sets of each exercise (1 set equals 9 completed stations). After completing 1 station, participants moved to the next station. One exercise in each station was done ± 30 seconds, while one circuit (1 set) was about 15-20 minutes. Then, the rest between stations was 20 seconds. The rest between sets was given 2 minutes. Meanwhile, conventional weight training was done with several repetitions for one form of exercise. Each exercise involved 1 place, 10 reps, and 3 sets (same place). The rest was given between sets for 2-minute. After that, it was continued to the next exercise with the same conditions (repetitions and sets were the same up to station 9).

These two forms of weight training treatment have something in common as they both increase leg muscle strength. In addition, the station number consists of 9 places with the same movements, and the length of treatment is ± 6 weeks atthe same time. The facilities and infrastructure used are the same. In addition, the order of the exercises (warm-up, core exercises, and cool-down), the method of taking the initial load and adding it, and the number of repetitions are the same. On the other hand, the fundamental difference between the two forms of weight training treatment lies in the rest period and the move to the next exercise.

Instrument

Motor skills data was obtained through the Barrow motor ability test (Fraser, 1966). This test consisted of a long jump without a prefix, zig-zag running, and throwing a medicine ball. Meanwhile, leg muscle strength was obtained through a leg dynamometer test. During this test, participants wore a belt, then stood with their knees bent (angle ± 45º). According to Barry and Jack, the participants pulled as hard as possible, and the needle on the tool showed the score (kg). The assessment was the recording by searchingfor the best score from 3 trials with an accuracy level of 0.5 kg (Sumaryanti & Ndayisenga, 2019).

Statistical analysis

Descriptive analysis was used to determine the characteristics of each treatment group data. While the normality test was analyzed based on the standard residual value, homogeneity was analyzed using Levene's test. Then, a two-way factorial ANOVA test was employed to analyze the difference in effect. This study also conducted Tukey's follow-up test to analyze significantly different groups or better results on leg muscle strength. All data in this study were analyzed using the IBM SPSS statistical program.

Results

This study found that the average leg muscle strength results for groups A1 and A2 were 74.56 and 71.72, respectively. For groups B1 and B2, the averages were 74.33 and 71.94. The average leg muscle strength results for groups A1B1 and A2B1 were quite high, 78.22 and 70.44. Slightly lower averages were shown by groups A1B2 and A2B2, where the averages were 70.89 and 73.00. This showed that the average of the A1B1 group was better than the other treatment groups (see Table 3 and Figure 2). Table 4 and Figure 3 also show that the normality and homogeneity tests of the data are normally distributed and homogeneous ($P > 0.05$).

Table 3. The results of the leg muscle strength of each treatment group

Group	*n*	Min	Max	*M* ± *SD*
A1	18	65.00	80.00	74.56 ± 3.27
A2	18	68.00	77.00	71.72 ± 2.37
B1	18	68.00	80.00	74.33 ± 3.18
B2	18	65.00	78.00	71.94 ± 3.26
A1B1	9	76.00	80.00	78.22 ± 1.20
A2B1	9	68.00	72.00	70.44 ± 1.42
A1B2	9	65.00	78.00	70.89 ± 3.12
A2B2	9	70.00	77.00	73.00 ± 2.50

Note- The dependent variable is leg muscle strength, the unit is kg, "A1" is circuit system weight training, "A2" is conventional, "B1" is high motor skills, "B2" is low motor skills, "A1B1" is circuit system weight training and high motor skills, "A2B1" is conventional weight training and high motor skills, "A1B2" is circuit system weight training and low motor skills, "A2B2" is conventional weight training and low motor skills.

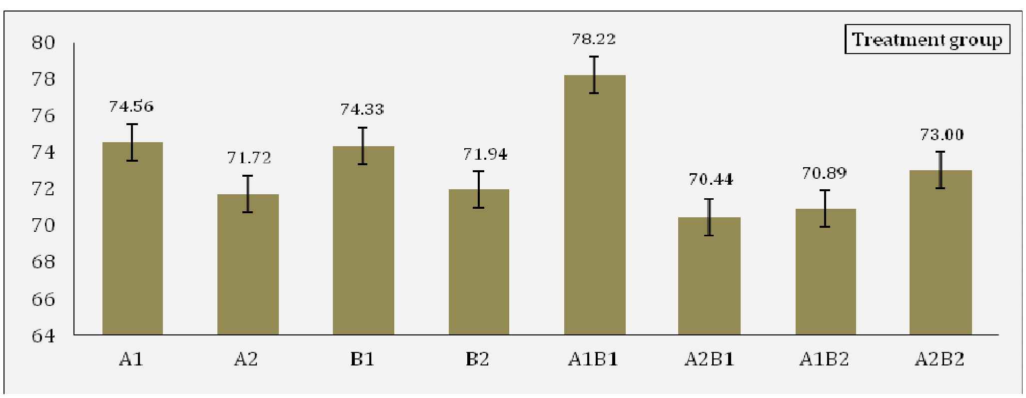
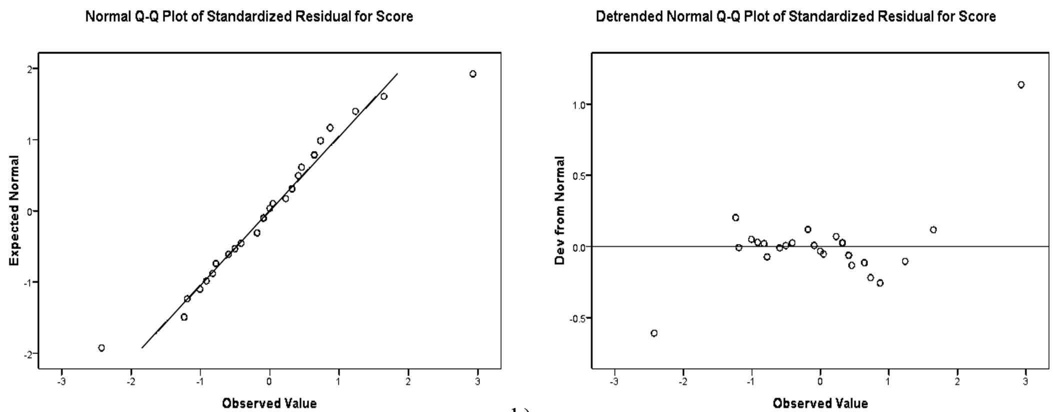


Figure 2. The average leg muscle strengths of each treatment group

Table 4. Normality and homogeneity testing

Normality test						Homogeneity test		
Kolmogorov-Smirnov			Shapiro-Wilk			Levene's		
Statistic	***df***	***P***	**Statistic**	***df***	***P***	***df1***	***df2***	***P***
0.098	**36**	**0.200**	**0.964**	**36**	**0.285**	**3**	**32**	**0.164**

Note- Data is normally distributed and homogeneous (P > 0.05).



a) b)

Figure 3. a) Graph of normality plot, b) Graph of detrended normality plot

Table 5 below provides the results of the two-way ANOVA test. The table shows that the results of leg muscle strength for groups A1 and A2 ($P < 0.05$) and groups B1 and B2 ($P < 0.05$) are significantly different. Figure 4 adds that there is a significant interaction between groups A and B ($P < 0.05$). To determine which treatment group had a better effect on leg muscle strength, a follow-up test was carried out using the Tukey test.

As presented in Table 6, Tukey's follow-up test analysis showed that group A1 was better than group A2 ($P < 0.05$) in improving leg muscle strength. This was evidenced by the averages of 74.56 > 71.72. Similarly,the results of leg muscle strength in group B1 were better than group B2 ($P < 0.05$), as shown by the average of 74.33 > 71.94. The leg muscle strength in the A1B1 group was the highest and far better than those in the A2B1 group ($P < 0.05$). The average was 78.22 > 70.44. Then, the results of leg muscle strength in the A1B2 group did not differ significantly from the A2B2 group ($P > 0.05$), which was evidenced by the average of 70.89 < 73.00.

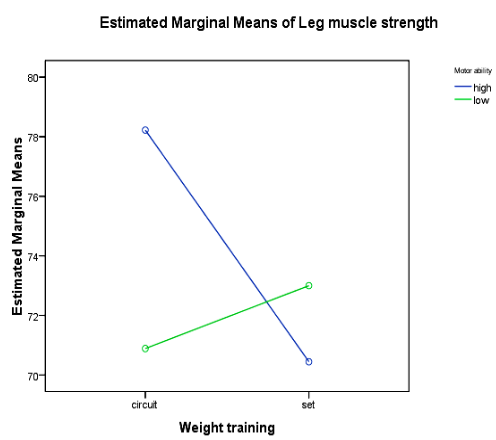


Figure 4. The interaction between weight training and motor skills

Table 5. Two-way factorial ANOVA

Source	Type III Sum of Squares	*df*	Mean Square	*F*	*P*
Corrected Model	343.63	3	114.54	19.43	0.000
Intercept	192.57	1	192.57	32.66	0.000
Weight training (A)	72.25	1	72.25	12.25	0.001
Motor skills (B)	51.36	1	51.36	8.71	0.006
Weight training (A)*motor skills (B)	220.03	1	220.03	37.32	0.000
Error	188.67	32	5.90		
Total	193.10	36			
Corrected Total	532.31	35			

*Note- The dependent variable is leg muscle strength, "weight training"- a significant difference was found between groups A1 and A2 (P < 0.05), "motor skills"- a significant difference found between groups B1 and B2 (P < 0.05)," weight training*motor skills"- there is a significant interaction between groups A and B (P < 0.05).*

Table 6. Tukey's test

Compared Groups	Tukey's	*P*	Conclusion
A1 and A2	4.96	0.024	Significant
B1 and B2	4.17	0.035	Significant
A1B1 and A2B1	9.61	0.000	Significant
A1B2 and A2B2	2.61	0.136	Not significant

Note- The dependent variable is leg muscle strength. The difference is significant ($P < 0.05$).

Discussion

These findings indicated that leg muscle strength given weight training with a circuit system was better than the conventional. The finding also reveal interaction between weight training and motor skills on leg muscle strength. The results of leg muscle strength given weight training with a circuit system prove this because it is better than the conventional for high motor skills. Meanwhile, for low motor skills, both forms of training can be given. However, the results can be better if the low motor is given conventional weight training. These results confirm earlier research revealing circuit training programs can increase muscle strength (Giannaki et al., 2015; Schmidt et al., 2015; Sonchan et al., 2017). Circuit resistance training is a time-saving exercise modality that aims to develop skeletal muscle and cardiovascular fitness (Kolahdouzi et al., 2018). Previous studies, also reported that this exercise is very effective for increasing performance in untrained men (Harber et al., 2004). Moreover, other reports find the efficacy of the training to increase muscle mass (especially muscle strength) among the elderly with various health conditions (Buch et al., 2017).

Circuit resistance training replaces high-volume resistance and aerobic-based exercises. The rest time is very quick, between 15 to 30 seconds. It also saves time and provides a stimulus for increased muscle strength, endurance, and cardiovascular fitness. Thus, the current research prefers moderate-intensity circuit training to conventional forms of resistance training. Circuit training is more likely to maintain cardiac output and systemic blood flow than traditional. The training is very good at keeping blood pressure to raise gradually and left ventricular burden (Montero et al., 2015). Previous studies supported this finding as the metabolism of this type of circuit training is higher compared to traditional resistance training (Pichon et al., 1996), even compared to a combination of traditional resistance training and aerobic training (Myers et al., 2015). In addition, circuit training outperforms traditional strength trainingin reducing body fat mass among the elderly (Romero-arenas et al., 2013).

Participants who barely train andtake partearly in resistance training typically have poor fitness levels and coordination when performing the exercises (Lasevicius et al., 2018). Thus, all loading schemes provide sufficient stimulus to increase muscle strength (Harris et al., 2004). One approach that is deemed effective in increasing the responsiveness of resistance training is periodization. It is carried out by varying training variables. It allows the participants to adapt the training in their own way (Headley et al., 2011; Kraemer et al., 2002). Then, various repetitions can be done as they are usefulfor developing muscle hypertrophy and strength (Kraemer et al., 2002). Plenty of research in the past reported that training planned according to the basic principles of exercise would produce the desired effect (Mario et al., 2022a; Marioet al., 2022b; Pagliara et al., 2020; Santos et al., 2020).

In order to increase strength and muscle mass, training with a load between 65% to 85% of maximum dynamic strength (1RM) is recommended (American College of Sports Medicine, 2009). Likewise, several studies have shown that low to moderate intensity (30% to 50% 1RM) exercise generates more muscle mass than higher-intensity training (Ogasawara et al., 2013; Schoenfeld et al., 2015a). Interestingly, electromyographic studies show that muscle activation is greater in high versus low-intensity resistance training (Schoenfeld et al., 2014b). The results of this study recorded an interaction between weight training and motor skills on leg muscle strength. In this regard, muscle strength is perceived essential for the development of motor skills (Malina, 2004) and functional abilities (e.g. changes in motor unit coordination) and structural adaptations as a result of resistance training impacting changes in motor skills (Behringer et al., 2011). Organizations (such as the NSCA, UKSCA, and BASES) have developed statements about why youth should engage in resistance training. One of the main benefits is the positive effect of resistance training on motor skills (Lloyd et al., 2014). Thus, motor skills need to be considered to determine the form of weight training that is suitable for leg muscle strength.

The results of leg muscle strength given weight training with a circuit system are better than conventional exercises for high motor skills. Previous studies reported that motor skills are an indicator that determines the extent to which individuals can carry out directed (movement-related) goals (Robinson et al., 2015). This includes the implementation of the circuit system. In a circuit system, individuals move from one exercise to the next with short periods and little rest between exercises (Kolahdouzi et al., 2018) so that the individual will make corrections to the movements made and do it again so that the next movements are better. Meanwhile, for low motor skills, both forms of training can be given. However, the results will be better on conventional. This is because the individual does it according to the instructions ordered by the instructor, and each exercise is done in 1 place before moving to the next form of exercise in the same way. That is, this exercise can be done simultaneously. The fundamental difference between the two forms of weight training treatment lies in the rest period and the move to the next exercise. From the differences in the implementation of the two forms of weight training, the results of leg muscle strength will be better if given conventional weight training for low motor skills. This research has been done as much as possible to avoid errors during treatment. Despite the promising findings, however, this study still has drawbacks. First, this study only applied two forms of weight training treatment (circuit and conventional systems) and two levels of motor skills (high and low). After that, the sample was rather small, i.e., 36 students in the sports coaching department (a not trained category in weight training). Thus, future research requires a larger size and trained samples. This study was only conducted ± 6 weeks with a frequency of 3 times per week. A longer study is recommended to get better results. Then, control of the sample is only carried out during the treatment schedule (such as rules during treatment, implementation of weight training, explanations about nutrition, and rest). Therefore,errors may occur outside the treatment schedule.

Conclusions

This study concludes that motor skills need to be considered in weight training (circuit and conventional systems) because they can lead to optimal leg muscle strength results. In accordance with these findings, the results of leg muscle strength given weight training with a circuit system are better than conventional (average, 74.56 > 71.72). After that, this study finds an interaction between weight training and motor skills on leg muscle strength. The results of leg muscle strength given weight training with a circuit system are better than conventional for high motor skills (average, 78.22 > 70.44). The results of leg muscle strength given weight training with circuit and conventional systems did not differ significantly for low motor skills (average, 70.89 < 73.00). However, the results would be better if given conventional weight training for low motor skills. This can be seen from the average comparison of the two. These findings are significant because they provide information about motor skills in weight training that might be useful for fitness instructors, weight training practitioners, and athletes in increasing leg muscle strength. Future research is needed by involving other forms of weight training and related factors in weight training, the number of samples with trained categories, and a longer time for treatment.

Conflicts of interest- The authors report that there is no potential conflict of interest.

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