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SHORT COMMUNICATION

Does the addition of lower-body aerobic exercise as a warm-up improve upper-body resistance training performance more than a specific warm-up alone?

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Objective: This study aimed to examine whether the addition of lower-body aerobic exercise as a warm-up (LGw) improves upper-body resistance training (RT) performance more than a specific warm-up (Sw) alone and to investigate whether maximal muscular strength modulates the performance-enhancing effect of LGw.

Design: Randomized crossover design.

Methods: Fourteen male participants performed 3 sets of 80%1RM bench press under two warm-up conditions. In one condition, the participants performed only a Sw for the bench press exercise. In the other condition (LGw + Sw), the participants performed cycling for 20 minutes and the Sw for the bench press exercise.

Results: There was no statistically significant difference in the total number of repetitions (REPTOTAL) and the mean propulsive velocity (MPV) of the barbell during the concentric phase between the Sw and LGw + Sw. Also, 1RM did not modulate the relationship between Sw and LGw + Sw for REPTOTAL and maximum MPV among all sets.

Conclusion: This study suggests that the LGw in addition to the Sw does not have large additional effects on performance during upper-body RT. In addition, maximal muscular strength does not modulate the performance-enhancing effect of the LGw on upper-body RT performed at 80%1RM.

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Key words: ■ acute effect ■ cross-transfer ■ muscle fiber ■ general warm-up ■ muscle strength

INTRODUCTION

A warm-up involves preparatory exercises before the main activity and is considered beneficial for improving performance and reducing the risk of injury.[1,2] A widely practiced warm-up consists of a general warm-up (Gw) and a specific warm-up (Sw). The Gw involves low-intensity aerobic exercise to increase muscle temperature, while the Sw involves exercises to activate a neuromuscular system and rehearse main activity.

Maximal muscular strength is considered an important physical variable in any athletic performance,[3] and resistance training (RT) is an effective means of enhancing maximal muscular strength. General guidelines recommend performing a warm-up before RT.[4] In fact, some scientific evidence supports the effects of an Sw on RT,[5,6] but few reports are available on a Gw. A few studies have reported that 15-20 minutes of cycling at 40-60% of maximum heart rate (HRMAX) improved one repetition maximum (1RM) leg press.[7,8] These results suggest that lower-body aerobic exercise as a Gw (LGw) improves the quantity and quality of lower-body RT.

The performance-enhancing effects of a warm-up would be associated with an increase in muscle temperature,[9,10] and lower-body aerobic exercise increases upper-limb muscle temperature.[11] Therefore, an LGw also has the potential to improve performance during upper-body RT. However, the only study to our knowledge that examined the effects of LGw on upper body RT reported that LGw did not increase the number of repetitions (REP) for bench press and arm curl.[12] These results would be attributed to the facts that Ribeiro et al. (2014) recruited participants who had not performed RT for at least 6 months, and had the participants perform repetitions-failure tasks four times in a week. These facts are considered to have led to fatigue and influenced the results, so further studies with due consideration of fatigue are needed.

It has been suggested that increasing total load (sets x repetitions x load) leads to greater muscular adaptation.[13] If there is no time limit, adding sets or other resistance exercises are effective means of increasing the total load. On the other hand, for those who would like to perform not only RT but also light aerobic exercise, which is beneficial for body mass and body fat loss as well as health[14] within a limited training time, increasing REP in each set without adding other sets and resistance exercises are effective means of increasing the

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total load. Therefore, it is meaningful to investigate the effect of LGw on REP by performing a repetitions-failure task.

In addition, although warm-up needs to be individualized to optimize the effectiveness, but few studies have examined the relationship between individual characteristics and performance improvement. Gray et al. (2005) have reported that individuals with a higher percentage of myosin heavy chain (MHC) IIA had greater increases in average and peak power during sprint cycling by increasing muscle temperature.[10] In addition, the relative MHC IIA content can account for approximately 30% of the shared variance in isoinertial, isometric, and isokinetic strength indices.[15] Thus, maximal muscular strength is an indicator of MHC IIA content and has the potential to be a variable that modulates the performance-enhancing effect of LGw.

Therefore, this study aimed to examine whether the addition of the LGw improves performance during the upper-body repetitions-failure task more than a Sw alone and maximal muscular strength is a variable that modulates the performance-enhancing effects of the LGw.

METHODS

Experimental approach to the problem

This study employed a crossover design, in which the participants performed 3 sets of bench press at 80%1RM until voluntary exhaustion under 2 different warm-up conditions more than three days after measuring their maximal muscular strength. In one condition (Sw), the participants performed only a specific warm-up for the bench press exercise. In the other condition (LGw + Sw), the participants performed a general warm-up with cycling and a specific warm-up for the bench press exercise. The order of the two conditions was randomized. The two conditions were separated by at least 4 days and performed at the same time of the day. The temperature in the laboratory was maintained within a standardized range of 22-24°C. In addition, we instructed the participants to abstain from strenuous physical activity, creatine, and caffeine for 48 hours before the experiment.

Participants

This study included fourteen men (age: 23.0 ± 1.6 years, body mass: 73.7 ± 12.4 kg, height: 176.4 ± 6.4 cm, training experience: 5.0 ± 2.0 years, training frequency: 2.4 ± 1.1 times/week, bench press 1RM: 87.5 ± 13.3 kg) who had at least one year of RT experience. In addition, the participants were able to perform bench press with a load greater than their body mass and had no upper-body injuries. This study was approved by the ethics review board of the University of Tsukuba. Written informed consent was obtained from all of the participants before beginning any experimental procedures.

Maximal muscular strength measurements

Following standard procedures,[16] the bench press 1RM was directly measured. First, the participants performed 5 minutes of cycling using Wattbike trainer (Wattbike Ltd, Nottingham, UK) and 5 static stretching exercises of the muscle groups involved in the bench press: around the wrist, shoulder, chest, and lower back muscles for 20 seconds each. Then, the participants performed 10, 8, and 3 repetitions of bench press using, 20 kg, 50%, and 70% of their estimated 1RM. The rest periods between sets were 2 minutes. After the warm-up, 3-6 trials were performed to determine the 1RM. After each trial, the load was increased or decreased by 5 or 10 kg. This process was repeated until failure. The rest periods between each trial were 3-5 minutes. The participants were instructed to keep the back of their heads, shoulders, and hips in contact with the bench during the exercise. Both feet were firmly grounded, and their knees were bent at approximately 90 degrees. The range of motion was defined as lowering the barbell until it touched the chest and raising it until the elbow joint was fully extended. The participants were instructed not to bounce the barbell on their chest, and the grip width was standardized by measuring the distance between their index fingers.

Specific warm-up protocol

The participants arrived at the laboratory and rested for 5 minutes. Then, they performed 1 set each of the bench press at 40%1RM for 5 repetitions, at 60%1RM for 3 repetitions, and 80%1RM for 1 repetition. The rest period between sets was 2 minutes. Based on previous studies, this protocol was designed to meet 4 conditions: progressively increasing load, including sets performed at 60-80%1RM, and multiple repetitions and sets.[17,18]

General and specific warm-up protocol

The participants arrived at the laboratory and rested for 5 minutes. Afterward, they performed cycling at 60-70 rpm using Wattbike trainer (Wattbike Ltd, Nottingham, UK) for 20 minutes. During cycling, the participants monitored their heart rate and adjusted the pedal load to maintain 60% of the predicted HRMAX (calculated as 208 - [0.7*age]).[19] Based on previous studies, the intensity and duration of the LGw were selected to increase upper-limb muscle temperature by approximately 1°C.[11] The Sw was performed 2 minutes after the LGw.

Performance test

3 minutes after the end of the warm-up protocol, the participants performed 3 sets of bench press at 80%1RM with each set performed to failure. The barbell was lowered for 2 seconds and raised as quickly as possible. The rest period between sets was 3 minutes. The participants followed the same instructions for the proper form that were provided during the 1RM measurement.

Data measurement

Polar H10 (Polar Electro Oy., Kempele, Finland) was used to measure the heart rate (HR). HR was recorded at a sampling frequency of 1 Hz. The average heart rate at each set and rest was calculated and analyzed.

Lactate Pro 2 (Arkray Inc., Kyoto, Japan) was used to measure the blood lactate (BLa). The blood samples were collected one minute before the start and one minute after the end of

Table 1 Measured variables during performance test

		Set 1 pre	Set 1 post	Set 2 pre	Set 2 post	Set 3 pre	Set 3 post
BLa [mmol/l]	Sw	1.8 ± 0.5	4.5 ± 0.8	6.0 ± 1.6	6.5 ± 0.9	7.0 ± 1.3	7.0 ± 1.3
	LGw + Sw	2.2 ± 0.6	5.2 ± 0.9	6.3 ± 1.5	7.1 ± 1.5	7.5 ± 2.0	7.6 ± 1.8
	ES	0.53	0.51	0.24	0.17	0.24	0.46
		Set 1	**Rest 1**	**Set 2**	**Rest 2**	**Set 3**	
HR [bpm]	Sw	109.3 ± 16.9	87.2 ± 11.4	108.6 ± 16.4	87.8 ± 11.6	106.8 ± 15.8	
	LGw + Sw	114.3 ± 15.0	94.1 ± 10.9	115.6 ± 12.4	94.3 ± 8.9	110.0 ± 11.7	
	ES	0.45	0.58	0.41	0.60	0.31	
		Set 1	**Set 2***	**Set 3**	**Total**		
REP [n]	Sw	10.2 ± 1.8	6.1 ± 1.0	4.3 ± 1.5	20.6 ± 3.3		
	LGw + Sw	10.1 ± 1.7	6.9 ± 0.9	3.9 ± 1.0	20.9 ± 2.5		
	ES	0.07	0.66	0.51	0.16		
		Set 1	**Set 2**	**Set 3**			
MPV [m/s]	Sw	0.41 ± 0.08	0.32 ± 0.06	0.28 ± 0.04			
	LGw + Sw	0.41 ± 0.07	0.33 ± 0.07	0.27 ± 0.05			
	ES	0.00	0.31	0.22			

Data are presented as the mean ± standard deviation
BLa, blood lactate; ES, effect size; HR, heart rate; LGw, lower-body aerobic exercise performed as a general warm-up; MPV, mean propulsive velocity; REP, the number of repetitions; Sw, specific warm-up
* $p < 0.05$ (Sw vs. LGw + Sw)

each set.

REP for each set was recorded. One repetition was counted when the barbell was lowered until it touched the chest and then raised until the elbow joint was fully extended.

During the performance test, we measured the mean propulsive velocity (MPV) of the barbell during the concentric phase which has a strong correlation with 1RM.[20] For each repetition, MPV was measured using Vitruve (SPEED4LIFTS S.L., Madrid, Spain) at a sampling frequency of 100 Hz. The maximum value of each set and the maximum value among all sets were analyzed.

Statistical analysis

The Shapiro-Wilk test was performed to check whether all variables were normally distributed. The results showed that MPV and the total number of repetitions (REPTOTAL) were normally distributed, while BLa, HR, and REP were not. Therefore, for verification of differences between Sw and LGw + Sw in MPV, we used a parametric two-way (condition x time or set) ANOVA test. Before performing a parametric two-way ANOVA, Mauchly's test was used to test for sphericity. When a violation of sphericity occurred, the Greenhouse-Geisser corrected p-value was reported. In cases of a significant interaction effect or main effect for the condition, post-hoc comparisons were conducted using paired t-tests with Bonferroni correction to compare Sw with LGw + Sw. Paired t-test was also used to compare REPTOTAL between the two conditions.

For verification of differences between Sw and LGw + Sw in BLa, HR, and REP, we used an aligned rank transformed repeated-measures nonparametric two-way (condition x time or set) ANOVA test.[21] In cases of a significant interaction effect or main effect for the condition, post-hoc comparisons were conducted using Wilcoxon signed-rank test with Bonferroni correction to compare Sw with LGw + Sw.

A moderation analysis was performed to test whether directly measured 1RM is a variable that modulates the effect of LGw on REPTOTAL and maximum MPV during the performance test.[22] The analysis was performed in two cases: for all participants and for the 13 participants excluding one participant whose 1RM was 2.83*SD higher than the mean value. 1RM of the 13 participants, excluding the participant whose 1RM was 2.83*SD higher than the mean value, were within the mean ± 1.0*SD.

The statistical significance was set at $p < 0.05$. To assess the magnitude of differences between Sw and LGw + Sw, effect sizes (Pearson's r) were calculated using the t-values from paired t-tests and z-values from non-parametric tests as appropriate.[23,24] All statistical analyses were performed using the SPSS software version 28.0 (IBM Corp, Armonk, USA).

RESULTS

Blood lactate

There was no statistically significant interaction effect (condition x time) for BLa ($p = 0.298$). However, there was a significant main effect for the condition ($p = 0.025$), and BLa was significantly higher in the LGw + Sw than in the Sw ($p = 0.013$). Also, main effect for the time was revealed for BLa ($p < 0.001$).

Heart rate

There was no statistically significant interaction effect (condition x time) for HR ($p = 0.973$). However, there was a significant main effect for the condition ($p = 0.024$), but there was no statistically significant difference between the LGw + Sw and the Sw. Also, main effect for the time was revealed for HR ($p < 0.001$).

The number of repetitions

There was a significant interaction effect (condition x set) for REP ($p = 0.004$), and the LGw + Sw was significantly higher than the Sw in Set 2 ($p = 0.013$). No statistically significant difference was revealed for Set 1 ($p = 0.782$), Set 3 ($p = 0.059$), and REPTOTAL ($p = 0.565$) between the LGw + Sw and Sw.

Mean propulsive velocity during the concentric phase

There was no statistically significant interaction effect (condition x set) for MPV ($p = 0.383$). Also, no main effect for the condition was revealed for MPV ($p = 0.959$). A main effect for the set was revealed for MPV ($p < 0.001$).

Moderation analysis

Analysis for all participants showed that 1RM modulated the relationship between Sw and LGw + Sw for MPVMAXIMUM ($r = -0.544$, $p = 0.044$), but not modulated REPTOTAL ($r = 0.180$, $p = 0.538$). Analysis for the 13 participants, excluding one participant whose 1RM was 2.83*SD greater than the mean value, showed that 1RM did not modulate the relationship between Sw and LGw + Sw for REPTOTAL ($r = 0.049$, $p = 0.873$) and MPVMAXIMUM ($r = 0.230$, $p = 0.450$).

DISCUSSION

This study revealed that the LGw did not significantly increase REPTOTAL and MPV during the bench press exercise. On the other hand, the LGw tended to sustainably increase HR during the performance test and significantly increased REP in Set 2. The increase in HR would be associated with an increase in muscle blood flow, which would promote the removal of lactate and hydrogen ions produced during exercise.[25] Therefore, the increase in HR may contribute to reducing fatigue-induced performance deficits. Bogdanis et al. (1996) have reported that cycling at 40% maximal oxygen uptake to increase HR during the rest period between sets of sprint cycling (2 sets x 30 seconds) prevented a decrease in cadence from the 1st set to the 2nd set.[25] Thus, the sustained increase in HR resulting from performing the LGw may contribute to preventing the reduction in REP from Set 1 to Set 2.

Regarding the moderation analysis, we confirmed that the participants whose 1RM was 2.83*SD higher than the mean had a very large influence on the results. Specifically, the correlation coefficient (r) changed by 0.724 when the participant was included and excluded. Therefore, we decided that the results of the 13 participants without the participant were more appropriate and discussed them. Contrary to our prediction, this study suggested that 1RM did not modulate the performance-enhancing effects of the LGw. In formulating this prediction, Gray et al. (2005), to whom we refer, reported that individuals with a greater percentage of MHC IIA, which is associated with muscular strength,[15] had greater increases in average and peak power during sprint cycling as a result of increased muscle temperature. In contrast, the performance test in our study was the 80%1RM bench press, not sprint cycling. This difference would be one of the reasons why 1RM did not modulate the performance-enhancing effects of LGw. To our knowledge, no studies have examined the relationship between muscle fiber composition and changes in performance due to increased muscle temperature during high-force, low-velocity exercise. Therefore, there is a need to investigate the relationship between muscle fiber composition and changes in performance due to increases in muscle temperature during high-force, low-velocity exercise, such as resistance exercise, and to further investigate whether muscular strength modulates the performance-enhancing effects of LGw during high-velocity exercises, such as sprint cycling and bench press throw.

However, this study has several limitations which should be addressed. The first limitation is that this study did not measure muscle temperature, muscle blood flow, and muscle fiber composition. Therefore, it is necessary to investigate the effects of these physiological variables on the variability of performance during RT. The second limitation is that this study only examined the acute effects of the LGw, so the effects of the LGw on long-term muscle adaptation are unclear. A third limitation is that the participants in this study were only young men who routinely perform RT. In order to obtain more universal findings on the effects of the LGw on upper-body RT, it is necessary to examine the effects of the LGw on individuals who have different maximal muscular strength from those of the participants in this study (e.g., powerlifters, women).

CONCLUSION

This study suggests that the LGw in addition to the Sw does not have large additional effects on performance during upper-body RT. In addition, maximal muscular strength does not modulate the performance-enhancing effect of LGw on upper-body RT performed at 80%1RM.

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REFERENCES

1) Bishop D. Warm up II: Performance changes following active warm up and how to structure the warm up. *Sports Med* 2003; 33: 483-498.
2) Safran MR, Garrett WE, Junior Seaber, AV et al. The role of warm-up in muscular injury prevention. *Am J Sports Med* 1988; 16: 123-129.
3) Young WB, Jenner A, Griffiths K. Acute enhancement of power performance from heavy load squats. *J Strength Cond Res* 1998; 12: 82-84.
4) Coburn JW, Moh HM. NSCA's Essentials of Personal Training 2nd Edition. *Human Kinetics* 2012.
5) Alves RR, Viana RB, Silva MH et al. Postactivation potentiation improves performance in a resistance training session in trained men. *J Strength Cond Res* 2021; 35: 3296-3299.
6) Conrado de Freitas M, Rossi FE, Colognesi LA et al. Postactivation potentiation improves acute resistance exercise performance and muscular force in trained men. *J Strength Cond Res* 2021; 35: 1357-1363.
7) Abad CC, Prado ML, Ugrinowitsch C et al. Combination of general and specific warm-ups improves leg-press one repetition maximum compared

with specific warm-up in trained individuals. *J Strength Cond Res* 2011; 25: 2242-2245.
8) Barroso R, Silva-Batista C, Tricoli V et al. The effects of different intensities and durations of the general warm-up on leg press 1RM. *J Strength Cond Res* 2013; 27: 1009-1013.
9) de Ruiter CJ, Jones DA, Sargeant AJ et al. Temperature effect on the rates of isometric force development and relaxation in the fresh and fatigued human adductor pollicis muscle. *Exp Physiol* 1999; 84: 1137-1150.
10) Gray SR, De Vito G, Nimmo MA et al. Skeletal muscle ATP turnover and muscle fiber conduction velocity are elevated at higher muscle temperatures during maximal power output development in humans. *Am J Physiol Regul Integr Comp Physiol* 2005; 290: 376-382.
11) Kenny GP, Jay O. Sex differences in postexercise esophageal and muscle tissue temperature response. *Am J Physiol Regul Integr Comp Physiol* 2007; 292: 1632-1640.
12) Ribeiro AS, Romanzini M, Schoenfeld BJ et al. Effect of different warm-up procedures on the performance of resistance training exercises. *Percept Mot Skills* 2014; 119: 133-145.
13) American College of Sports Medicine, American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 2009; 41: 687-708.
14) Donnelly JE, Hill JO, Jacobsen DJ et al. Effects of a 16-month randomized controlled exercise trial on body weight and composition in young, overweight men and women: the Midwest Exercise Trial. *Arch Intern Med* 2003; 163: 1343-1350.
15) JJürimäe J, Abernethy PJ, Quigley BM et al. Differences in muscle contractile characteristics among bodybuilders, endurance trainers and control subjects. *Eur J Appl Physiol Occup Physiol* 1997; 75: 357-362.
16) Brown LE, Weir JP. ASEP procedures recommendation I: Accurate assessment of muscular strength and power. JEPonline 2001; 4: 1-21.
17) Wilson JM, Duncan NM, Marin PJ et al. Meta-analysis of postactivation potentiation and power: effects of conditioning activity, volume, gender, rest periods, and training status. *J Strength Cond Res* 2013; 27: 854-859.
18) Ribeiro B, Pereira A, Neves PP et al. The Role of Specific Warm-up during Bench Press and Squat Exercises: A Novel Approach. *Int J Environ Res Public Health* 2020; 17: 6882.
19) Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. *J Am Coll Cardiol* 2001; 37: 153-156.
20) García-Ramos A, Pérez-Castilla A, Villar Macias FJ et al. Differences in the one-repetition maximum and load-velocity profile between the flat and arched bench press in competitive powerlifters. *Sports Biomech* 2021; 20: 261-273.
21) Wobbrock JO, Findlater L, Gergle D et al. The aligned Rank transform for nonparametric factorial analyses using only ANOVA procedures. *Proceedings of the International Conference on Human Factors in Computing Systems* 2011; 143-146.
22) Montoya AK. Moderation analysis in two-instance repeated measures designs: Probing methods and multiple moderator models. *Behav Res Methods* 2019; 51: 61-82.
23) Rosnow RL. Beginning behavioral research: A conceptual primer. 2nd eds. New Jerseyt: Prentice-Hall 1996.
24) Kerby DS. The simple difference formula: An approach to teaching nonparametric correlation. *Innov Teach* 2014; 3.
25) Bogdanis GC, Nevill, ME, Lakomy HK, et al. Effects of active recovery on power output during repeated maximal sprint cycling. *Eur J Appl Physiol Occup Physiol* 1996; 74: 461-469.
26) Racinais S, Oksa J. Temperature and neuromuscular function. *Scand J Med Sci Sports* 2010; 20: 1-18.