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Effects of Two Types of Warm-Up Exercises on Vital Capacity and Forced Vital Capacity Values

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Abstract

Valuable information can be obtained about the respiratory system when performing lung function tests. These tests show differences in pulmonary functional quantities, which can be attributed to many factors. Some factors that may significantly affect the optimal pre-test values for pulmonary function may appear, including the subject's physical condition before testing. This study aims to analyse the physiological effects of various types of warm-ups exercises and their effect on pre-test results of respiratory variables of Vital Capacity (VC) and Forced Vital Capacity (FVC). Sixteen healthy males participants ages (19–21) years (20.08±1.55 years) were intentionally selected. The homogeneity of age, height, mass, Vital Capacity (VC), and Forced Vital Capacity (FVC) was verified. The results of VC and FVC tests were taken before and after field and laboratory warm-ups; the laboratory warm-up was performed on a treadmill. The study revealed significant differences in the VC results between non-warm-ups compared with the VC predicted values. No significant differences between field and laboratory warm-ups compared with VC predicted value were found. Significant differences in the VC results after the field and laboratory warm-ups compared to non-warm-up results were recorded. The study showed significant differences in the FVC results between non-warm-ups compared with FVC predicted value. No significant differences between field and laboratory warm-ups compared with FVC predicted value were found. Significant differences in the FVC results after the field and laboratory warm-ups compared to non-warm-up results. We observed that warm-up exercises had a positive effect on variable-related results for VC and FVC, especially when the warm-up was in the lab.

Keywords: *laboratory warm-up, field warm-up, respiratory muscles, pulmonary function*

Introduction

Valuable information can be obtained on the strength of the respiratory muscles, the mechanical properties of the lungs, the movement of the rib cage, and the efficiency of gas exchange processes when performing pulmonary function tests. In the area of sports, the effects of training on pulmonary functions are the primary aim, so a pulmonary test should utilise the best method to obtain the best value at pre-test, which should be close or similar to the predictable results shown by the device. In addition, this value should be adopted as a correct baseline for the post-test of the sports training programme. These tests show differences in pulmonary function quantities values that may be attributed to factors associated with instrumentation, measurement-based experience, temperature, and a subject's response to following the instructions. It was observed that all of the factors mentioned above make the actual values differ from their corresponding predicted ones. For instance, these factors could be controlled by the calibration of testing instruments, laboratory settings, and training on the optimal test performance. However, we show some other factors that may significantly affect the optimal test values of the pulmonary functions, including the physical condition of the subject before the test.

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Gradation and preparation are important and necessary in all human activities, both mentally and physically. Prior to any physical activities, warm-ups must be sufficiently performed in order to prepare the body to be active and ready for the assigned activities. It is known that warm-up exercises are very important and highly recommended by physical fitness experts. These exercises are considered indispensable to facilitate the movement of muscles in all directions and increase muscular activity. Performing warm-up exercises results in physiological and chemical changes in the muscular structure, which in turn increases elasticity and power (Alanazi, 2016; Morrin & Redding, 2013).

"It is important that warming ups should be specific to the exercise that will follow, which means that exercises (of warming up) should prepare the muscles to be used and to activate the energy systems that are required for that particular activity" (Kar & Banerjee, 2013).

It is noted that most studies in this field of research focus primarily on the effects of exercise and training on respiratory functions, but not on the importance of lung function pre-test values and the best way to conduct the pre-test. The researchers also noted, through many functional tests of the respiratory system (because they are responsible for exercise physiology laboratories in their colleges), that the actual values do not match or come close to much of the expected values that the device gives after entering the data subject's (length, weight, gender, smoker or not, etc.). Therefore, the researchers suggested preparing respiratory muscles before beginning respiratory tests by warming up and determining the effects of warm-ups on the results of some respiratory variables (Flesch & Dine, 2012). Moreover, determining the best way to warm-up in such functional tests should aid in obtaining actual pulmonary values near to their predicted ones, to be a baseline for the pre-post of the sports training programme.

The current research addresses the following questions: 1) Do warm-ups affect the values of the results of Vital Capacity (VC) and Forced Vital Capacity (FVC); 2) What type of warm-ups are appropriate and which have the greatest effects on the outcome of VC and FVC

Methods

Subjects

The subjects of this study were a purposeful sample chosen from 58 students from the third academic class at the Faculty of Physical Education at KOYA University. After excluding females, athletes, and obese students, the subjects were 24 students homogeneous in age, height, and body mass but not in VC and FVC. Therefore, the outliers values above and below the VC and FVC results were omitted. The final and main subjects were 16 students at age 19–21 years and homogeneous in the variables shown in Table 1.

Table 1. Homogeneity statistics of Subjects

Variables	Statistical parameters	
	Mean±SD SD ±	Skewness
Age (year)	20.08±1.55	0.29
Height (cm)	172.3±5.59	0.79
Body Mass (kg)	69.5±4.65	0.74
VC (L)	4.05±0.43	0.60
FVC (L. s-1)	3.72±0.36	0.35

Legend: VC - vital capacity; FVC- Forced vital capacity

Anthropometric Measurements

Two anthropometric measurements were taken: height and weight. They were measured in triplicate with the median value used as the criterion. The height was recorded during inspiration using a stadiometer (Charder Electronic, Taichung, Taiwan) to the nearest 0.1 cm. The subject was asked to stand upright on the stadiometer barefoot, the metal plate of the stadiometer was placed on the top of the subjects' head, and the results were recorded. Weight was measured by digital standing scales (Detecto solo Digital Physician Scale, Brooklyn, NY, USA) to the nearest 0.1 kg with the subjects barefoot and in shorts (Eston & Reilly, 2009; Koley, 2011)

Spirometry

The VC test is the total volume of air that can be exhaled after maximum inhaling by using a spirometer for measuring lung function type (CHESTGRAPH HI-301, Tokyo, Japan). VC testing begins by guiding the subject in performing the appropriate technique. The subjects need to understand that they have to fill and empty their lungs as much as possible. The VC testing was performed with a subject using a mouthpiece and wearing a nose clip. The VC was performed conveniently but not inappropriately slow, except for near inspiration and expiration. All subjects maximumly exhale, then maximally inhale, and finally maximally exhale again. Technicians should carefully monitor this subject to ensure that his lips are closed and there are no leaks or obstructions to the mouthpiece (Miller, Hankinson, Brusasco, Burgos, & Others, 2005).

The FVC is the amount of air exhaled forcefully and quickly after inhaling as much as possible. The subject takes a deep breath in, as large as possible, and blows out as hard and fast as possible and keeps going until there is no air left using a mouthpiece and wearing a nose clip (Moore, 2012).

Independent variables

Laboratory warm-ups were carried out according to the modified Bruce protocol test on an institutional treadmill (Vacuumed, California, USA), and the warm-up period was 6 minutes. Compared to the standard Bruce protocol, the modified Bruce protocol has two warm-up stages, each lasting 3 minutes. The first stage is at 1.7 mph and a 0% grade, and the second stage is at 1.7 mph and a 5% grade. Therefore, this protocol is convenient for the aim of this study; it simulates or parallels the field warm-ups (Harris & White, 2009). The field warm-ups were carried out outside the laboratory for 6 minutes, where the subjects were given a light jog for 2-3 minutes; after that, they were assigned leg, hip, arm, and chest exercises (Lee, 2014).

Final experiment

The final experiment included three tests on three separate days for each subject. For tests warm-up, the subjects were divided into four groups with four subjects for each group to ensure no significant time lags when waiting for the test. On the first day, the test of VC and FVC was performed without a warm-up. On the second day, the test of VC was performed after a 6-minute warm-up on the treadmill under laboratory control followed by rest for 3 minutes before the test, then repeated after a two-hour interval but after a 6-minute field warm-up, also followed by rest for 3 minutes before the test. On the third day, the test of FVC performed after a 6-minute warm-up on the treadmill under laboratory control, then repeated after the two-hour interval but after a 6-minute field warm-up, either way, followed by a rest for 3 minutes before the tests; this is shown in Table 2.

Table 2. Steps to perform the final experiment

Day	Groups	Subject number for each group	Warm-up type	Duration of warm-up	Rest	Test type
Day 1	Group 1	16	Non	Non	2 hours between VC and FVC test	VC
						FVC
Day 2	Group 1	4	field warm-up	6 minutes	3 minutes	VC
	Group 2					
	Group 3					
	Group 4					
	2 hours interval between field warm-up and Laboratory warm-up in VC test					
	Group 1	4	Laboratory warm-up	6 minutes	3 minutes	VC
	Group 2					
	Group 3					
	Group 4					
Day 3	Group 1	4	field warm-up	6 minutes	3 minutes	FVC
	Group 2					
	Group 3					
	Group 4					
	2 hours interval between field warm-up and Laboratory warm-up in FVC test					
	Group 1	4	Laboratory warm-up	6 minutes	3 minutes	FVC
	Group 2					
	Group 3					
	Group 4					

Statistical analysis

Paired t-test statistical analysis was used to find the differences between the means of three independent VC and FVC tests, Non-warm-up, Laboratory warm-up and Field warm-up and to compare them with predicted values for both variables. The one-way analysis of variance (ANOVA) is used to determine any statistically significant differences between the means of three independent VC and FVC tests, Non-warm-up, Laboratory warm-up and Field warm-up. A post-hoc test of less significant difference (LSD) was used for situations in which the findings have already obtained a significant F-test and for adding exploration of the differences among means to provide specific information on which means are significantly different from each other. Descriptive statistics of mean, standard deviation, and skewness coefficient were utilized to describe the basic features of the data in this study and to provide simple summaries about the sample and the measures. SPSS version 18.0 was used for all analyses (SPSS Inc., Chicago, IL, USA).

Results

Table 3 shows that the mean VC values are 4.05 for non-warm-up, 4.52 for laboratory warm-up, and 4.46 for field warm-up. Additionally, it explains that the mean FVC values are 3.72 for non-warm-up, 4.11 for laboratory warm-up, and 4.05 for field warm-up.

In Table 4, a statistical comparison is made using a t-test to compare non-warm-up and warm-ups values with the predicted values. The predicted or optimal values are obtained via the spirometer based on the input data (height, weight, gender, etc.); we did obtain the predicted values of VC and FVC from Knudson's reference values, which are the closest fit to the lung function of subjects. Knudson's reference values are included in the settings of the utilized spirometer; we choose these values to be a predicted reference. Table 4 shows that a statistically significant difference is found in the VC variable when non-warm-up results are compared with the predicted value ($t=-4.92$, $p=0.001$). Relatedly, no significant difference between the field

Table 3. Descriptive statistics of VC and FVC at various warm-ups

Warm-up type	Functional variable	
	VC	FVC
	SD±Mean	SD±Mean
Non-warm-up	0.43±4.05	0.36±3.72
Laboratory warm-up	0.40±4.52	0.44±4.11
Field warm-up	0.52±4.46	4.05±0.32
predicted value	0.32±4.78	0.33±4.28

Legend: VC - vital capacity; FVC- Forced vital capacity

warm-up and the predicted value is noted (t=- 1.74, p=0.102).

Additionally, no significant difference is found between the laboratory warm-up and the predicted value (t=-1.63, p=0.123) in the VC variable. The same table shows a statistically significant difference in the FVC variable when non-warm-up results are compared with the predicted value (t=-4.54, p=0.001) and that there is no significant difference between the field warm-up and the predicted value (t=-1.54, p=0.138). No significant difference between the laboratory warm-up and the predicted value (t=-1.43, p=0.171) in the FVC variable is found.

Table 4. VC & FVC results compare with predicted value by Paired t- test

	Mean±SD	t	p
Vital Capacity (VC)			
N warmup- predicted value	-0.73±0.59	-4.92	0.001*
F warmup – predicted value	-0.31±0.71	-1.74	0.102
L warmup- predicted value	-0.25±0.62	-1.63	0.123
Forced Vital Capacity (FVC)			
N warmup- predicted value	-0.57±0.50	-4.54	0.001*
F warmup - predicted value	-0.24±0.63	-1.56	0.138
L warmup- predicted value	-0.18±0.51	-1.43	0.171

Legend: F warm-up – Field warm-up; L warm-up – Laboratory warm-up; N warm-up – non-warm-up; * - p<05

Table 5 shows that a statistically significant difference was found among the three levels of VC's test on the types of warm-up (F=5.208, p=0.009). A statistically significant difference was found among the three levels of FVC tests on types of warm-up (F=4.703, p=0.014).

LSD post-hoc tests in the table indicate that there were significant mean differences of VC testing between the Non-warm-up group and both the Field warm-up group (p<0.012) and the Laboratory warm-up group (p<0.005); this is shown in Table 6. LSD Post hoc tests in the table indicate that there were significant mean differences in the FVC testing between the Non-warm-up group and both the Field warm-up (p<0.021) and the Laboratory warm-up (p<0.006)groups; this is shown in Table 6.

Table 5. One-way ANOVA of VC and FVC at various warm-ups

Variables	Statistical treatments	Sum of squares	Mean square	F	p
VC / L	Between group	2.23	1.105	5.238	0.009*
	Within group	9.51	0.211		
	Total	11.72			
FVC / L.s	Between group	1.37	0.688	4.703	0.014*
	Within group	6.58	0.146		
	Total	7.96			

Table 6. LSD of VC and FVC among various warm-ups

Variables	Group	Comparison group	Mean differences	p
VC	Non-warm-up	Field warm-up	-0.42	0.012*
	Non-warm-up	Laboratory warm-up	-0.48	0.005**
	Field warm-up	Laboratory warm-up	0. 51	0.731
FVC	Non-warm-up	Field warm-up	-0.32	0.021*
	Non-warm-up	Laboratory warm-up	-0.38	0.006*
	Field warm-up	Laboratory warm-up	-0.063	0.65

Discussion

This study aims to determine the effects of the warm-up type on VC and FVC for health practitioners of sports activity but not athletes. Moreover, it aims to examine the most beneficial warm-up type that increases the VC and FVC values and attempts to match them with the predicted values. VC test differences were found between warm-ups and both field warm-up and laboratory warm-up.

We know that the results of the respiratory tests depend on the efficiency of the respiratory system. One factor that negatively affect the efficiency of the respiratory system are respiratory diseases. Another factor is the extent to which respiratory muscles participate in the test, which is a group of muscles that can reach 16 muscles between primary and secondary or the supporting muscles (Kraemer, Fleck, & Deschenes, 2014). Excluding the fact that the participants suffer from respiratory diseases because the initial results were presented to the respiratory physician who confirmed their safety, we still have the effect of the respiratory muscles on the results of the VC test, which was affected by warm-ups, whether in the laboratory or field.

The researchers attribute the significant differences between the results of field warm-up and laboratory warm-up when compared with the results of no warm-up in the VC test to the effectiveness of warm-up in the preparation and adaptation of the respiratory muscles in the implementation of the VC test technique. McGuff and Little mention that no one argues that athlete's connective muscles and connective tissue should be warm and that viscosity should be reduced before engaging in any activity (Kraemer et al., 2014). Warming up, as well as injury prevention, includes other benefits, such as increased speed and efficiency muscle contraction, tissue compliance, enhanced utilized oxygen delivery, and facilitating the transmission of nerve impulses (V. L. Katch, McArdle, & F. I. Katch, 2011). This was achieved by the increase in the VC values after the warm-ups.

In the VC equation (VC=IRV+Vt+ERV), we see that a VC variable that depends on three elements. The most important aspects in this equation variable is the inspiratory reserve volume (IRV), the maximum amount of air that can be taken by the inspiration, and the expiratory reserve volume (ERV), the maximum amount of air can be expelled by exhalation. These are two forced operations that require the insertion of extra muscles into action (Guyton & Hall, 2006). The Vt variable is excluded because the tests are taken at rest. We notice that the IRV and ERV variables influence the value of VC. These variables depend on the extent of the respiratory muscles involved in this action; like other skeletal muscles, they are all affected by warm-ups. When referring to the comparison of probability levels between no warm-up with field warm-up and no warm-up with laboratory warm-up, we note that the greatest significant differences go to laboratory warm-up. The researchers believe that the continuity of work on the treadmill has placed a greater burden on the respiratory muscles than field warm-up. The degree of respiratory muscle mobilization in laboratory warm-up was more than an intermittent exercise in the field warm-up. According to Nicholas Ratamess 2012, an important component of aerobic exercise is the level of continuity and the size of skeletal muscles involved in the work (Ratamess, 2012).

Aerobic exercises on a treadmill requires the use of large groups of body muscles and thus an uptake in the amount of oxygen. High-intensity aerobic exercises improve airflow in the respiratory system. When a large lung volume is required, the lung is enlarged substantially and thus has significant contraction force, and the diameter of the respiratory passages is expanded to reduce airflow resistance (Park & Han, 2017). All of this requires an increasingly effective contribution from the respiratory muscles, and thus reflects positively on the VC test.

Warming up increases the elasticity of the skeletal muscles, as well as increasing the breathing rate and in the air entering the lungs to obtain oxygen. Hayes and Karman indicate that FVC is not only limited to the exhalation muscles' effort but also by the elasticity of the lungs (Hayes & Kraman, 2009). That happened in both warm-ups to the FVC variable; because the respiratory muscles are skeletal muscles, they were positively affected by the warm-up; also, the increase in the respiratory rate increases the movement of the lungs in the entry and exit of the air, which led to increasing elasticity for lungs.

From another perspective, there were significant differences in the results of VC, in both laboratory and field warm-ups when compared to non-warm-up. Researchers believe that the subjects that were able to make a significant difference in the VC test can make the same differences in the FVC test in favour of the warm-up. Yuan, He, Xu, Wang and Casaburi (2014) point out that in normal or healthy people, there is a slight difference between the results of VC and FVC, and sometimes that difference may be absent.

When comparing the calculated mean for the FVC test in laboratory warm-up with their results in field warm-up, we observe that the preference goes to laboratory warm-up. Rawashdeh and Alnawaiseh (2018) indicate that high-intensity exercises on the treadmill have a positive effect on the FVC in healthy people.

According to the results of this research, we noted that the warm-up exercises had a positive effect on the results related to the variable VC, especially when warm-up was in the laboratory and on the treadmill. In addition, warming up had a significant effect on the results of the variable FVC and in both warm-ups, but it was more effective when in the laboratory and on the treadmill. Researchers recommend that it is more helpful to have a warm-up before starting a VC or FVC test. Thus, the study recommends warming-up on the treadmill to improve the pulmonary function of the VC and FVC before performing lung function tests. Researchers also recommend researching other respiratory variables after introducing warm-up exercises.

Perspectives

Several studies were conducted on the number of attempts that should be given to the topics to achieve credibility in results VC and FVC. In addition to studies on the effect of exercises on two variables VC and FVC. However, no study on preparing the subject physically before performing the tests. The current study showed that the warm-up before the test has a significant effect on the initial results of the tests VC and FVC and nearer to the expected values that the device gives when entering the initial information of the subject in it. There is still an urgent need for more studies on other respiratory variables to understand the effect of warming up before testing.

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Conflict of Interest
The authors declare that there are no conflicts of interest.

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