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Research article

THE EFFECT OF FOOTBALL SHOULDER PADS ON PULMONARY FUNCTION

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ABSTRACT

Restriction of expansion of the lungs or chest wall impedes inflation of the lungs during inhalation. Functional changes occurring during such restriction include reduced pulmonary and/or chest wall compliance, decreases in pulmonary function, and ultimately a decrease in exercise performance. Such restriction can be seen in several pathologic conditions such as scoliosis or obesity, as well as occupational situations such as the wearing of bullet-proof vests. This study investigated the hypothesis that tightened football shoulder pads produce decrements in pulmonary function similar to those shown in previous studies involving other external chest-wall restricting devices. In this study, 24 subjects, all members of a collegiate division IAA football team and used to wearing the pads, performed standard pulmonary function tests while wearing no pads (control, CTRL), wearing pads that were not secured (pads loose, PL) and while wearing pads secured "game-tight" (pads tight, PT). The data showed that both forced vital capacity (FVC) and forced expiratory volume in one second ($FEV_{1.0}$) were significantly decreased in the PT condition compared to either the CTRL or PL condition, with no changes in the $FEV_{1.0}$/FVC ratio or peak expiratory flow rate. These results are consistent with a restrictive condition and support our hypothesis that tightened shoulder pads reduce pulmonary function. Further studies remain to be performed to determine whether these changes lead to decreased exercise performance and whether equipment modifications can be made to limit alterations in pulmonary function without decreasing the protective value of the pads.

KEY WORDS: Lung function, protective clothing, breathing capacity.

INTRODUCTION

In order to properly ventilate, both the lungs and the chest wall need to expand with relatively little effort. If this cannot occur, i.e. if lung or chest wall expansion is hindered, either ventilation will be relatively insufficient or the respiratory muscles will undergo undue fatigue. Restrictive conditions of the chest wall occur in diseases such as obesity or scoliosis, but also with occupational situations such as the wearing of bullet-proof vests. A restrictive condition results in decreases in lung volumes such as the forced vital capacity (FVC) or the forced expiratory volume in one second ($FEV_{1.0}$) without impeding airflow or the ratio between FVC and $FEV_{1.0}$. Legg (1988) reported that there was a decrease in FVC and $FEV_{1.0}$ when wearing three different types of body armor, but no change in the $FEV_{1.0}$/FVC ratio. Muza et al. (1989) reported similar results while wearing weighted backpacks.

Anecdotal reports allude to shortness of breath in players involved in American football during practice and game situations. Along with this, current football shoulder pads are recommended to

extend to the xyphoid process (Lavery, 2000), completely covering the front of the chest wall, where expansion takes place. This led us to suspect that a similar condition may occur with the wearing of this type of protective apparatus. If such is the case, there is a high likelihood that exercise capacity could be impaired (Coast and Cline, 2004), particularly later in a game, where aerobic recovery is necessary for optimal performance. Therefore, the purpose of this study was to determine whether wearing shoulder pads would adversely affect pulmonary function in a group of men accustomed to wearing them. Specifically we tested the hypothesis that wearing shoulder pads tightened to the degree the players use them during a game would decrease FVC and $FEV_{1.0}$ without altering the ratio of these measurements or peak airflow. We also compared this condition to simply having the pads resting on the shoulders to ensure that any detriment in pulmonary function was due to the tightness of the apparatus and not the minor weight of the shoulder pads.

METHODS

Twenty-four males participated in this study. The subjects were 20.8 ± 1.6 (mean ± SD) years old with a mean weight of 103.4 ± 19.6 kg (228.2 ± 43.3 lbs) and a mean height of 1.85 ± 0.07 m (72.7 ± 2.8 in). All of the subjects were members of a NCAA Division IAA football team, and were accustomed to the football pads used in the study. The subjects were informed of the testing procedures, risks and benefits of the experiment and each signed an informed consent form approved by the University Institutional Review Board for Human Subjects in Research.

Upon recruitment and signing of the informed consent, subjects reported to the testing facility to perform standard pulmonary function tests. All tests were performed using a calibrated spirometer (Chest-Test, Vacumed, Ventura, CA) and procedures standardized by the American Thoracic Society (Buist, 1987). Tests were performed in the standing position under three conditions. In the control (CTRL) condition, the subjects wore no pads. They were asked to blow into the mouthpiece of the spirometer as hard and as completely as possible. A minimum of three tests trials were performed, with a maximum of five trials until at least two trials were determined to be acceptable (less than 100 ml difference). Between each trial, subjects were given 1-2 minutes rest to ensure adequate recovery. The other two conditions were performed with the shoulder pads on. In the "pads loose" (PL) condition, the shoulder pads were placed on the shoulders, but not secured by the straps. This condition allowed us to determine whether the pads alone had an effect by simply resting on the shoulders. The "pads tight" (PT) condition was performed with the shoulder pads secured by straps. In this condition, the subjects were instructed to put the pads on and secure them to the tightness they would in a game situation. The conditions were presented to the subjects in a randomized order such that four subjects completed each possible test order (e.g CTRL, PL, PT).

From each test, the following variables were measured: FVC, which is the maximal amount of air that can be exhaled following a maximal inhalation; $FEV_{1.0}$, which is the amount of air exhaled during the first one second of the maximal forced exhalation; the $FEV_{1.0}$/FVC ratio; and the peak expiratory flow rate (PEFR), which is the maximal flow rate during the expiratory maneuver. The FVC and $FEV_{1.0}$ are indicators of lung and chest wall volume, while the $FEV_{1.0}$/FVC ratio and the PEFR are indicators of airway patency. The best trial for each subject was used for analysis. Data were analyzed via one-way repeated measures analysis of variance (ANOVA) across the three conditions (CTRL, PL, PT). Significant results were further analyzed via Tukey's *post hoc* test. Significance was established at the 0.05 level.

RESULTS

The data showed that the athletes exhibited normal pulmonary function in terms of FVC (98.71 ± 6.34% predicted) (mean ± SD), $FEV_{1.0}$ (98.58 ± 7.62% predicted) and the $FEV_{1.0}$/FVC ratio (101.38 ± 8.11% predicted). This was shown as a group as well as individually, in that each person presented normal values, with the FVC ranging from 85 - 111% predicted, the $FEV_{1.0}$ ranging from 88 - 118% predicted and the $FEV_{1.0}$/FVC ratio ranging from 93 - 127% predicted.

The ANOVA revealed a significant difference in FVC across conditions ($p < 0.0001$). The *post hoc* test showed that there was a significant difference between the CTRL and PT conditions as well as between the PL and PT conditions, but no difference between CTRL and PL (Figure 1).

There was also a difference across conditions for $FEV_{1.0}$ ($p < 0.001$). As with FVC, the post hoc test revealed significant differences between the PT and the CTRL and PL conditions, but no difference between the CTRL and PL conditions (Figure 1). Neither the $FEV_{1.0}$/FVC ratio nor the PEFR were significantly different across the test conditions ($p = 1$ and $p = 0.569$, respectively).

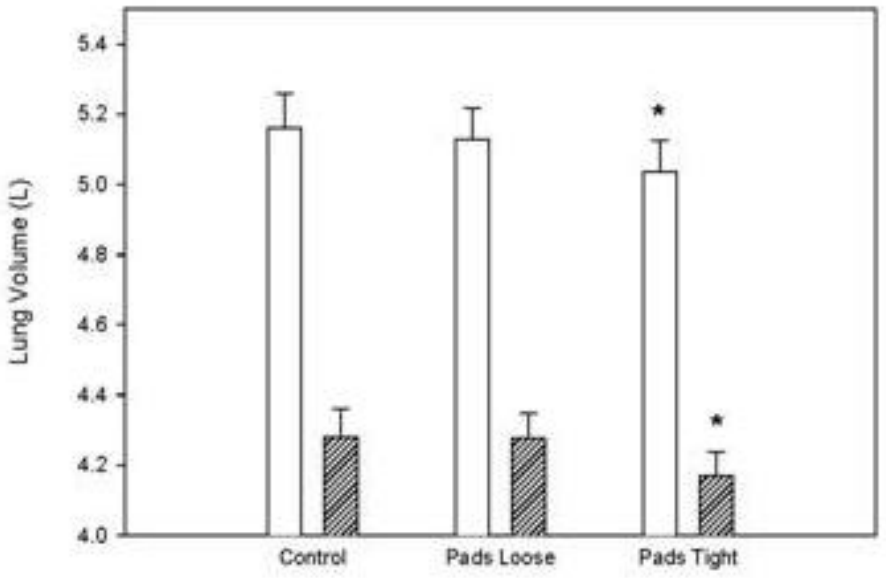

Figure 1. This figure shows the FVC and $FEV_{1.0}$ during control, pads loose and pads tight conditions. FVC is shown in the open bars, while $FEV_{1.0}$ is in the stippled bars. * different from Pads Loose and Control conditions.

DISCUSION

The purpose of this study was to determine whether football shoulder pads had an effect on pulmonary function at rest. The results of the study confirmed our hypothesis, in that there were decreases in lung volumes with the pads tightened, but not when the pads were simply resting on the shoulders. Further, there were no changes in either of the flow indices. These results show that shoulder pads tightened around the chest result in a restrictive-like condition in terms of pulmonary function.

Several studies have evaluated the effect of externally induced chest wall restriction on pulmonary function. In our laboratory, we evaluated both the effect of restriction on lung function and its effect on the energy cost of breathing (Cline et al., 1999; Gonzalez et al., 1999). Through the use of a variable-pressure restrictive device, we were able to show that a restrictive load that decreased FVC by approximately 100 ml, similar to that seen in this study, increased the oxygen uptake by approximately 100 $ml \cdot min^{-1}$ at a ventilation level of 90 $L \cdot min^{-1}$, or approximately 20% (Gonzalez, et al., 1999). Such an additional ventilatory requirement may be likely to limit the ability of an athlete to recover aerobically in the short period of time between plays in a game situation. Others have used artificial devices to cause chest wall restriction and have arrived at similar pulmonary function results (Bradley and Anthonisen, 1980; Dimarco et al., 1981; Hussain et al., 1985; Younes et al., 1990).

Two studies have evaluated specific occupational devices and their effects on pulmonary function. Legg (1988) used bulletproof vests such as those worn by police and military, and found decreases in FVC of 2-3%, similar to those seen in this study, with no change in flow parameters. Muza and colleagues (1989) evaluated pulmonary function in soldiers carrying loaded or unloaded backpacks. They too, found decreases in lung volume measurements with little change in airflow, suggesting a restrictive condition. To our knowledge no studies have been carried out using shoulder pads or similar apparatus. The decreases in pulmonary function seen in the reported studies, as well as the decreases we found in the current study, should have little or no consequence on a person at rest or performing low intensity exercise. They may be important, though, in situations in which exercise intensity is very high.

While anecdotal evidence indicates that dyspnea or breathlessness is not uncommon in football players, it is not well studied, and is, presumably, thought to simply be a result of exertion. This is likely to be a realistic attitude, but a restriction of the ability to expand the lungs and chest wall has been shown on several occasions to limit exercise, so may be an important factor in the capacity of football players, particularly later in a game. Results from our laboratory (Coast and Cline, 2004) show that restriction causing as little as a 150 ml decrease in FVC resulted in a decrease in maximal oxygen uptake (VO_2max) of approximately 5% in a population of healthy but relatively inactive subjects (VO_2max range 40.6 - 44.8 $ml \cdot kg^{-1} \cdot min^{-1}$). This may not seem like a large decrease in exercise capacity, and further, American football is not

typically considered a sport that relies heavily on aerobic energy formation. Recovery is aerobic in nature, though, and is required to be rapid (the short time between plays). Further, in higher fit subjects the VO_2max would likely be decreased to a greater extent than in sedentary individuals. Lindstedt et al. (1994) showed that VO_2max was decreased to a greater extent in more highly fit subjects than in sedentary ones in response to obstructed breathing. Therefore, it is possible, even likely, that aerobic capacity, and thus recovery capability, would be decreased in conditions of pulmonary restriction in this population.

CONCLUSION

In conclusion, we have shown that wearing football shoulder pads tightened to the extent found in game conditions decreases pulmonary function. To our knowledge, this is the first study to examine the effect of shoulder pads on pulmonary function. The level of decrease may be sufficient to decrease aerobic capacity, which could hinder recovery during the short rest periods found in a game. At present, there may not be a lot that can be done to alleviate this situation and maintain the protective properties of the shoulder pads. Further, any decrements in pulmonary function may even be greater than the decreases we found in this study because of the influence of very tight jerseys, often worn by players, which could further decrease pulmonary function. There may be new designs of shoulder pads that could be developed which would provide similar levels of protection without the pulmonary restriction. Other alternatives need to be examined, as do the direct effects of shoulder pad wearing on exercise capacity.

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KEY POINTS

- The shoulder pads used in American football extend to the xyphoid process and may provide a restriction to breathing. This was tested in the present study in 24 college-level football players with normal resting pulmonary function
- The results showed that there was a decrease in FVC of approximately 150 ml and a similar decrease in $FEV_{1.0}$.
- Similar decreases in pulmonary function have been shown to provide a limitation to exercise capacity in otherwise healthy adults.
- Further study is needed to determine whether these changes lead to decrements in performance.

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