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STRENGTH AND CONDITIONING PROGRAMMES FOR IMPROVING BACK MUSCLE FATIGABILITY IN FIREFIGHTERS

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Back pain and back-related injuries are common in firefighters. The purpose of this study was to compare the effectiveness of two different types of strength and conditioning programmes in improving back muscle fatigability in firefighters. A total of 12 male firefighters completed 16 weeks on supervised exercise intervention programme. The Functional Group was prescribed unilateral movements that mimicked the asymmetrical nature of firefighting tasks. The Conventional Group performed more bilaterally loaded, symmetrical exercise training. The lumbar extensor muscles' resistance to fatigue was assessed using the Modified Sorensen test with electromyography (EMG). The EMG median frequency slope was less steep ($p = 0.023$, $\eta^2_p = 0.420$) after training, indicating improvement in fatigability. There was no difference between the groups ($p = .605$, $\eta^2_p = 0.028$) and no interaction effect ($p = 0.245$, $\eta^2_p = 0.132$). In conclusion, a well-rounded strength and conditioning programme is promising in improving back muscle fatigability in firefighters.

KEYWORDS: firefighters, paramedics, electromyography, EMG

INTRODUCTION: Emergency response such as firefighting is an inherently dangerous occupation. Firefighters must be physically fit to effectively cope with the challenging demands during emergency situations and to reduce work-related injuries (Beach, Frost, McGill & Callaghan, 2014). Back pain and back injuries are common complaints among firefighters, possibly due to occasional exposures to strenuous and physically demanding tasks (Nazari, MacDermid & Cramm, 2020; Stassin, Games & Winkelmann, 2021).

An effective strength and conditioning programme is one method to improve back muscle strength and reduce the rate of back pain and/or injuries in firefighters (Abel, Palmer & Trubee, 2015). Conventional resistance training exercises (e.g. bench press, push-up, squat) are bilaterally symmetrical movements whereby the left and right limbs perform the same range of motion simultaneously. In firefighting work, however, the operational tasks such as manipulating an axe and handling casualties are not bilaterally symmetrical. Thus, it is of interest to design functional exercises that better simulate the asymmetrical and/or diagonal loading nature of the firefighting operational tasks. Deficit in lumbar extensor endurance has been reported in individuals with chronic low back pain compared with healthy controls (Ashmen et al., 1996; Klein et al., 1991). While there are no specific data on firefighters, runners with chronic low back pain demonstrated marked improvement in longissimus muscle fatigability after 8 weeks of training (Cai et al., 2017). Thus, it is reasonable to expect firefighters can benefit from strength and conditioning exercises in improving back muscle fatigability.

This study aimed to examine the effectiveness of two strength and conditioning programmes on back muscle fatigability in firefighters. It was hypothesized that functional training (experimental) would be more effective than conventional training (control) in improving the resistance to fatigue in lumbar extensor muscles.

METHODS: This study was approved by the Nanyang Technological University Institutional Review Board (IRB-2020-06-85). A total of 12 male participants who were full-time frontline

firefighters were recruited from convenience sampling. All participants provided written informed consent to enrol in the study. Participants were randomly allocated into one of the two exercise groups (Functional vs Conventional Groups) undergoing different types of strength and conditioning programmes for 16 weeks. The Functional Group (experimental) performed training exercises that simulate the asymmetrical and/or diagonal loading nature of the movements which they would encounter in their work routine. Examples of functional exercises include single-leg deadlift, kneeling single-arm press and single-arm dumbbell chest press. The Conventional Group (control) was prescribed conventional strength training that comprised bilaterally symmetrical multi-muscle group exercises (e.g. barbell back squat, push-up).

All training was conducted in the gym at the assigned fire stations under the supervision of the same researcher who was trained and experienced in strength and conditioning. Each training session consisted about 8 different exercises, with each session lasting from 45 minutes to 1 hour. The training load and training volume of the two groups were similar. Participants were asked to complete the exercise programmes on their duty day, two sessions per week for 16 weeks.

Before and after the 16-week intervention, the lumbar extensor muscles' resistance to fatigue was assessed using the Modified Sorensen test along with electromyography (EMG) (Cai et al., 2017). Participants were required to lie on an examining table in a prone position with the upper edge of the iliac crests aligned with the edge of the table and the lower body was being strapped down around the pelvis, knees and ankles (Figure 1a). Participants were asked to maintain a horizontal position for 2 minutes. The test would be terminated if participants failed to maintain the upper body in a horizontal position; only data during the stable holding phase would be analysed. During the test, lumbar extensors muscles activation (longissimus of both left and right sides) was captured using surface EMG. The electrodes were placed 2 cm lateral to the L1 spinous process, parallel to the spine (Figure 1b). Raw EMG data were band-pass filtered at 20 to 450 Hz and then analyzed in the frequency domain. To examine the back muscle's resistance to fatigue, the median frequency slope of EMG signals was calculated from the power density spectrum obtained using a fast Fourier transform (Cai et al., 2017). Over the 2-minute period, the EMG median frequency slope would decline over time, with a steeper slope (i.e. more negative value) indicating a more fatigued muscle.

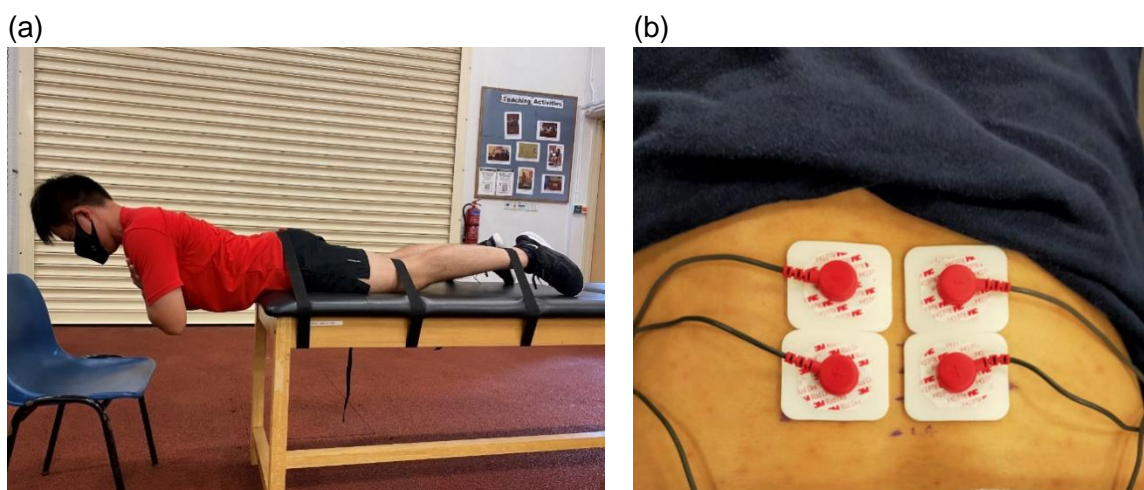


Figure 1: (a). Sorensen test to assess back muscles' resistance to fatigue. (b). Placement of EMG electrodes on the *longissimus* muscle on both left and right sides.

Statistical analysis was performed to compare the EMG median frequency slopes at pre-test and post-test across the Functional and Conventional Groups using a mixed-model Analysis of Variance. Statistical significance was set at 0.05. Data are expressed as mean (95% confidence interval, CI).

RESULTS: There was a significant main effect of time ($p = 0.023$, $\eta^2_p = 0.420$), with the EMG median frequency slope becoming less steep at post-test compared with pre-test (Figure 2). There was no significant difference between the Functional and Conventional Groups ($p = .605$, $\eta^2_p = 0.028$) and no interaction effect ($p = 0.245$, $\eta^2_p = 0.132$).

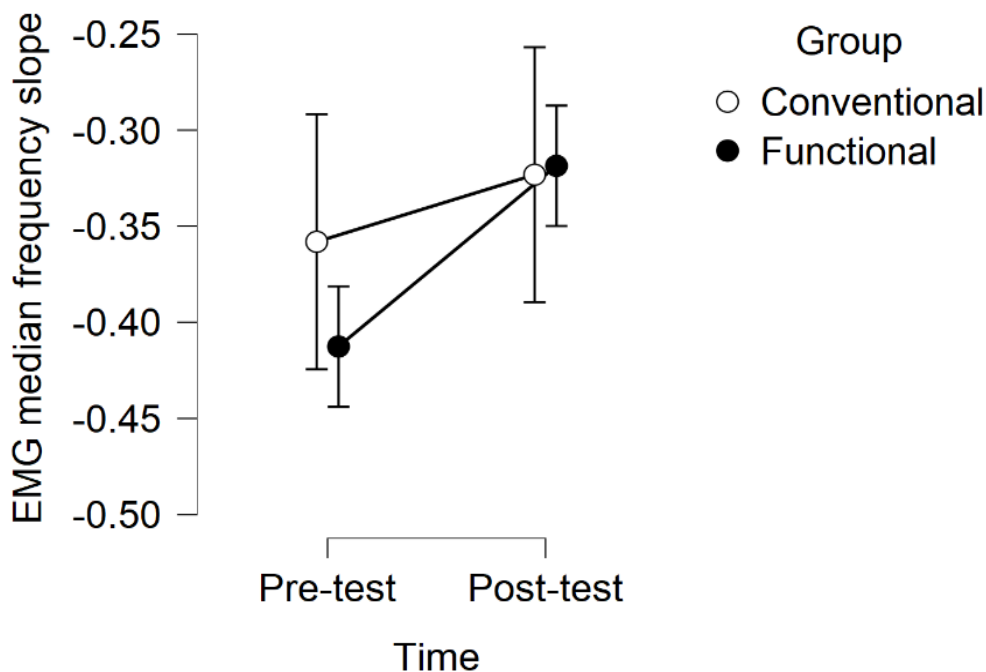


Figure 2: Resistance to fatigue of back muscles before and after 16 weeks of functional or conventional exercise training. Data are displayed as mean (95% confidence interval).

DISCUSSION: The present study compared the changes in lumbar extensor muscle fatigability after 16 weeks of training using functional or conventional exercises. It was found that the EMG median frequency slope became less steep after the exercise intervention but there was no difference between the two exercise types. These findings suggest that firefighters can improve the resistance to fatigue in their back muscles after engaging in a comprehensive strength and conditioning programme.

In the literature, deficit in lumbar extensor endurance has been reported in individuals with chronic low back pain compared with healthy controls (Ashmen et al., 1996; Klein et al., 1991). There are currently no data regarding the back muscles' EMG characteristics in firefighters or other emergency responders. For runners with chronic low back pain, one study demonstrated improvement in longissimus fatigability after 8 weeks of rehabilitation exercise training (Cai et al., 2017). The authors cautioned that despite statistical differences in EMG median frequency slope were found, the improvement of 0.046 was too small to overcome the minimal detectable changes (MDC, 95% CI) ranging from 0.11 to 0.17. Similar to the study by Cai and colleagues (2017), the present study also observed statistically significant but small improvement in lumbar extensor muscles EMG median frequency slope after 16 weeks of training (mean change 0.035 in the Conventional Group, and 0.094 in the Functional Group). Using isoinertial exercise intervention, however, researchers reported no change in muscle fatigability after a 12-week lumbar extensor training programme (Mannion et al., 2001). Future studies can further investigate the types and duration of exercise interventions, and search for optimal strength and conditioning programmes for prevention of back pain and injuries in firefighters. There are some limitations to the present study. First, the training plan was severely interrupted by COVID-19 pandemic with frequent changes and restrictions (e.g. closure of gym, change in work shift, group size limitation). As such, the training compliance rate was lower than

expected. On average, the participants completed a total 20 sessions over 16 weeks. Second, the post-test was conducted around the Ramadan fasting period during which the exercise and diet routines of our Muslim participants (11 out of 12) were affected. Thus, the post-test results may not fully capture the training effect accurately.

CONCLUSION: This study showed that a 16-week strength and conditioning programme was promising in improving lumbar extensor muscles' resistance to fatigue in male firefighters. The training effects were similar between functional training (which puts more emphasis on unilateral movements) and conventional training (which tends to be more bilateral symmetrical). Considering the small sample size, these findings are preliminary. Future studies can examine if long-term compliance to similar training programmes can improve occupational performance and/or to reduce the risk of injuries in firefighters.

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