BIOMECHANICS OF STATIONARY EXERCISE IN OVERWEIGHT AND NORMAL-WEIGHT CHILDREN

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The purpose of this study was to examine the differences in lower extremity kinematics and muscle activation patterns in normal weight and overweight children during stationary exercises at submaximal intensity. Twenty-five children (10-13 years) were recruited and classified as overweight (OW) and normal-weight (NW). Electromyography, the ratings of perceived exertion (RPE) and range of motion (ROM) of lower extremity joints were collected during stationary exercises. ANOVAs compared muscle activation, ROM and RPE between groups, and exercises. Compared to NW, OW experienced significantly greater RPE and muscle amplitude in all muscles apart from VL during stationary exercises. Children with greater mass adopt a more active neuromuscular strategy in order to provide greater stability and propulsion during stationary exercises.

KEYWORDS: electromyography, stationary running, frontal kick, butt kick.

INTRODUCTION: Stationary exercise is one of the most convenient and frequently prescribed exercises when a sufficiently large area for running is not available (i.e. classroom) or necessary equipment has not been resourced. Stationary exercises can also be recommended for health promotion and rehabilitation as they incorporate basic movement patterns and have benefits to musculoskeletal and cardiovascular systems (Alberton et al., 2011; Haddock et al., 2009).
Despite the popularity of stationary exercise as a fundamental component of rehabilitation and training protocols, there are no studies, to our knowledge, that focus on the biomechanical variables of diverse stationary exercises (i.e. stationary running, frontal kick and butt kick) in children. Without fully understanding the biomechanical differences that occur between stationary exercises in children, these activities cannot be accurately integrated into existing exercise prescription, particularly for children carrying excess mass. Therefore, the purpose of this study was to examine the differences in lower extremity kinematics and muscle activation patterns in normal weight and overweight children during stationary exercises (stationary running (SR), frontal kick (FK), butt kick (BK)) at submaximal intensity on dry land. It was hypothesized that muscle activation patterns will be different between OW and NW children at similar heart rate (HR) and range of motion (ROM) for all stationary exercises.

METHODS: Twenty-five children, aged 10-13 years (12 males, 13 females) were recruited through local schools to participate in the study. Participants were classified as overweight (N=10; age: 12.10 ± 1.22; 73.93 ± 17.11kg; 1.59 ± 0.11m; body fat percentage: 34.97±8.60) and normal-weight (N=15; age: 12.23 ± 1.08; 43.16 ± 7.54kg; 1.57 ± 0.11m; body fat percentage: 18.33 ± 4.87) based on the international cut-off points (Cole et al., 2000). An initial session was held to collect anthropometry measures and familiarize participants with SR, FK, and BK and Borg's rating of perceived exertion (RPE) 6-20 category scale (Borg & Kaijser, 2006).
A digital camera (240 Hz) was synchronised with 6 EMG channels of a wireless electromyography (EMG) system, (Model 542 DTS EMG, Noraxon US Inc., Scottsdale, AZ) to record kinematic data and muscle activation of rectus femoris (RF), vastus lateralis (VL), biceps femoris (BF), medial and lateral heads of the gastrocnemius (GAS-M and GAS-L) and tibialis anterior (TA) during stationary exercises. To enable the normalisation of the EMG signals, 3 sets of maximal voluntary isometric contractions (MVICs) were performed (5

seconds) for the selected muscles. In addition, reflective markers were placed on the anterior superior iliac spine (ASIS), iliac crest, greater trochanter, lateral femoral epicondyle, lateral malleolus and calcaneus in order to determine the hip, knee and ankle joints range of motion (ROM) throughout the stationary exercises. Each exercise was conducted for 5 minutes at submaximal intensity (60% heart rate). EMG signals, kinematic data, heart rate and RPE were collected from the 3rd to the 4th minute of each trial. The order of the exercises was randomly chosen, and the participants had an interval of 5 minutes' rest between exercises. EMG data were rectified and filtered using a bidirectional 8th order Butterworth bandpass filter (10-500 Hz). All EMG data were reported as a percentage of root mean square (RMS) values obtained in MVICs. The reflective markers were digitised manually in Vicon Motus into two-dimensional coordinates. All digitised data were filtered using a second order Butterworth low-pass filter with a cut-off frequency of 6 Hz.
The data processing was performed using Matlab R2015b (Mathworks Inc., Natick, MA, USA) and MRXP Master Edition, version 1.08.17 (Noraxon USA Inc., Scottsdale, AZ). The mean of the five selected cycles was measured for the presentation of the ROM and EMG data. From kinematic data, the selected consecutive strides were identified as those having low kinematic variability (lower extremity joint ROM ±5°). Repeated measures analysis of variance (ANOVA) was used to compare muscle activity patterns and ROM between groups, and exercises. An alpha level of .05 was used for all statistical tests.

RESULTS: There was no significant main effect for HR ($p < 0.05$) when comparing between groups or exercises. The RPE responses were significantly greater in OW children than NW children in SR (OW Mean ± SD 13.80 ± 0.63; NW = 11.66 ± 0.72), FK (OW = 13.90 ± 0.73; NW = 11.80 ± 0.67) and BK (OW =13.30 ± 0.94; NW =11.60 ± 0.82) exercises ($p < 0.05$). There were no significant differences for ROM between groups at ankle, knee and hip joints ($p = 0.194$) in each exercise. Figure. 2 demonstrates the muscle activity patterns for the RF, VL, GAS-M, GAS-L, TA and BF during SR, FK and BK. RF activation was greater in the OW group compared to the NW group across all exercises ($p < 0.05$). OW participants also had greater activation of GAS-M and GAS-L in comparison to NW peers during FK ($p < 0.05$) and BK ($p < 0.05$). The OW group showed significantly higher activation of TA ($p < 0.05$) and BF ($p < 0.05$) in all exercises compared to NW. VL activation was not significantly different between groups across all exercises ($p = 0.32$).

DISCUSSION: The results of this study showed that RPE was significantly higher in OW children during all exercises. This difference in RPE occurred despite the fact that HR was controlled between groups and exercises. The RPE results were also consistent with the EMG results of this study, as OW children had to utilise a higher percentage of their muscle activation capacity to perform the stationary exercises at a similar HR to their NW peers. The increased muscle activation and RPE support the suggestion that OW participants may work at a higher relative percentage of their capacity. These adaptations could be due to both deconditioning and higher load during moving excess mass. Additionally, the higher RPE scores could indicate a lack of enjoyment when performing stationary exercise, which is consistent with previous studies associating higher RPE values with lower rating of pleasure in OW participants (Ekkekakis & Lind, 2006).
Although RF activation was significantly higher in OW children, the activation pattern was similar across all exercises in both groups. The emphasis on knee extension and hip flexion in the SR and FK activities resulted in significantly higher RF activation compared to BK, which demonstrated greater knee flexion. These findings are consistent with previous research reporting higher RF activation in FK compared to other stationary exercises (Alberton et al., 2014). VL activation was consistent and not significantly different between groups and exercises and could be due to the role of VL muscle as a knee stabilizer during each of the stationary exercises (Alberton et al., 2014).
There was a similar level of gastrocnemius activation during SR for both groups. While the NW group did not demonstrate differences in gastrocnemius activation across exercises, the OW group had significantly greater activation in FK and BK than SR. The findings align with

previous gait research (Blakemore et al., 2013) that found longer duration of activation for gastrocnemius in OW children during walking. Greater impact during landing with excess body mass and a desire to increase stability at stance phase resulted in these higher activations within OW children. OW children may rely on greater gastrocnemius activation during FK and BK because of the required forefoot support, which was not present in the flatter foot posture during SR. In addition, gastrocnemius muscles showed significantly greater activation than other muscles ($p < 0.05$) in both groups, as the musculature is required to assist in vertical propulsion and absorb impact with forefoot strikes during stance phase of stationary exercises (Alberton et al., 2014; Fontana et al., 2012).

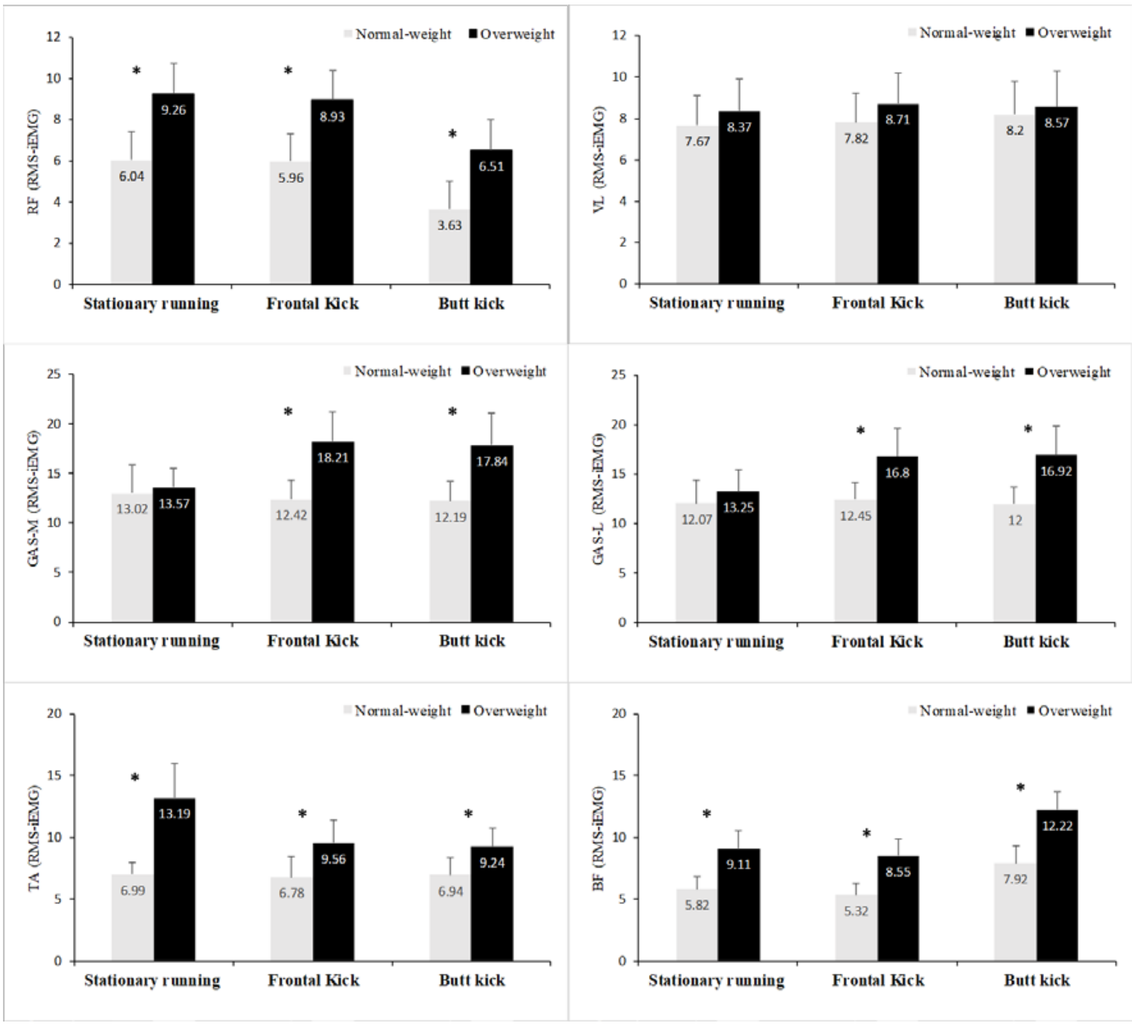

Figure 2: EMG activation pattern of rectus femoris (RF), vastus lateralis (VL), gastrocnemius medialis (GAS-M), gastrocnemius lateralis (GAS-L), tibialis anterior (TA) and biceps femoris (BF) between normal weight (NW) and overweight (OW) groups during different stationary exercises. * indicates significant differences between NW and OW groups

TA muscle showed significantly higher activation in OW children than NW in all exercises. TA presented greater activation in SR than other exercises in OW children, while there were no significant differences in the level of TA activation between exercises in NW children. SR was performed with more ankle dorsiflexion and a subsequent flatter foot posture than the other exercises. Thus, this exercise was probably performed by keeping the TA shortened and GAS lengthened throughout the cycle completed by OW children. As a consequence, there was a greater TA activation observed during SR than FK and BK in this group.

Due to the relationship of BF with RF as a force couple, BF presented inverse muscle activation patterns to RF throughout exercises. Specifically, SR and FK generated lower activation in BF than BK in both groups throughout the cycle. Similar to RF, GAS-M, GAS-L and TA, BF presented significantly higher muscle activation in OW children than their NW peers. The increase in excess mass would require greater activation of the hamstrings to propel the child during all exercises.

CONCLUSION: OW and obese children showed higher RPE and muscle activation during stationary exercise, suggesting that strength has not increased proportionally with mass in OW children. Subsequently, OW children need to use a greater percentage of their muscle capacity when performing submaximal stationary exercises. The variation in muscle activation between groups, as well as between exercises, indicates that stationary exercise can be prescribed to strengthen lower extremity muscles in overweight children, but mode and intensity must be considered. To inform injury risk as well as physical function, future research should include the analysis of ground reaction force, as well as implementation of other stationary exercises in a variety of weight bearing environments.

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