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The effect of exercise on motor performance tasks used in the neurological assessment of sports related concussion

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Running title: Exercise and sports concussion assessment
Abstract

Sports-related concussion is assessed using both cognitive and motor performance tasks. There is limited understanding how exercise affects these measures. The purpose of this study was to investigate the effect of moderate-intensity exercise on three selected measures of motor performance.

A repeated measures design was used to compare baseline motor performance scores to post-exercise scores with an exercise intervention modelled on the physiological demands of a team sport. Thirty physically active subjects performed timed motor performance tasks; Finger-to-Nose (FTN), Tandem Gait (TG) and Single Leg Stance (SLS). The tasks were administered twice pre-exercise and twice post-exercise.

FTN, TG and SLS demonstrated high test-retest reliability (ICC values > 0.8). Fifteen minutes of moderate intensity exercise caused a significant improvement in FTN (p = 0.0004) and TG (p = 0.0009), but not in SLS (p = 0.5068).

Improvement in the performance of motor tasks after exercise has implications for the immediate assessment of sports related concussion given that measures of motor performance are utilised in concussion assessment instruments.
It is estimated that approximately 300,000 sport related concussions occur in the United States annually.1 Athletes who are suspected of being concussed need to be screened by sideline sports medicine personnel to determine appropriate medical management.2,3 Commonly reported physical signs of concussion include impaired coordination, unsteady gait, and poor balance.2,3

Instruments such as the Sport Concussion Assessment Tool,3 Standardised Assessment of Concussion2, Balance Error Scoring System4 and the McGill Abbreviated Concussion Evaluation5 are side-line screening instruments used in the assessment of concussion that utilise motor performance measures to assist diagnosis. It is essential that assessment tools are reliable, easy to use in an athletic population, and scientifically valid. Moreover, it is critical to know how exercise affects these measures. If exercise adversely alters task performance, this could result in incorrect decisions being made concerning an athlete’s injury status and compromise return to play protocols.

The aim of this study was to determine the effect of moderate intensity exercise on measures of motor performance utilised in the neurological examination of athletes suspected of having sustained a concussion. A secondary aim was to determine the reliability of these measures.

METHODS

Subjects
A cohort of physically active tertiary students with no known neurological, musculoskeletal, or cardiovascular conditions volunteered. All subjects gave written informed consent and were screened with the Physical Activity Readiness Questionnaire.6 The study procedures were approved by the University of Otago Human Ethics Committee.

Design
A repeated measures design with an exercise intervention was used. The mode and intensity of exercise were selected to mimic the physiological demands of a team sport.

Procedure
All tasks were performed in a laboratory on solid wooden flooring and SLS on Foam required an additional closed-cell foam surface (Airex, Alusuisse, CH). Subjects dressed in their usual athletic attire, identified their dominant hand and leg and were briefed on the motor performance measures and exercise protocol. Practice of each measure was allowed up to 3-times. Three trials of each measure, were repeated at four fifteen-minute intervals (T-1,2,3,4). All measures were timed using a stopwatch accurate to 0.01s. The task order was randomised to avoid order bias.

Measures
The assessment of motor performance followed standardised protocols.7

FTN measured upper limb coordination and speed. The starting position was supported sitting with the dominant arm outstretched, shoulder flexed to 90° and the index finger pointed. The head remained stationary and eyes were open. When the
start signal was given, the subjects performed five successive FTN repetitions using
their index finger.

TG measured dynamic balance, speed and coordination.8,9 The subjects began the
task with their feet together behind a starting line. Subjects walked along a 38 mm
wide, 3 m line with an alternate foot heel-to-toe gait, turned 180° behind the end of
the line and returned to the start.

SLS on Floor and Foam was used to measure static balance. Subjects maintained
their balance to a maximum of 30 s while standing on their dominant leg with their
eyes closed on firm (SLS Floor) and foam surfaces (SLS Foam). Subjects were
instructed to keep their hands on their hips and their eyes closed. A rest was given
between each trial (10 s).

Exercise protocol
The intervention consisted of four stations with immediate transitions involving upper
and lower-body exercise that simulated the physiological demands of a rugby
game.10,11 Station-1 comprised a 3-minute exercycle (Monark 818e, Stockholm, SE).
Station-2 consisted of 4-minutes arm cranking (Monark 881, Stockholm, SE),
followed by 4-minutes treadmill (Quinton Medtrack, Rochester, NY) running
(Station-3). Station-4 comprised 4-minutes of rowing (Concept II, Morrisville, VT).
To standardise exercise intensity to a sport specific level, 75-85% of APMHR was
used.10,11 Heart rate was recorded using a Polar-F1 monitor (Gays Mills, WI).
Subjects quantified their rate of perceived exertion (RPE), using a 15 point (6-20)
Borg Scale.12

Statistical analysis
A priori level of significance of 0.05 was used and the data were analysed using linear
mixed models with a random subject effect to account for correlations within time
points and within subjects. The data were examined for skewness of the residuals and
where necessary a log transformation was applied. Intra Class Correlations’ (ICC)
were computed for the pre-exercise trials with the assumption of a random effect for
subjects. All statistical procedures were performed using SAS 9.1.2.13

RESULTS
Thirty physically active subjects (15M:15F) aged 18-25 years (mean 20.8±1.3) were
recruited (Table 1). All subjects were right hand dominant and 15 females and 12
males demonstrated right foot dominance. All subjects achieved the target exercise
intensity.

Table 1  Subject characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± SD Females (n = 15)</th>
<th>Range</th>
<th>Mean ± SD Males (n = 15)</th>
<th>Range</th>
<th>Mean ± SD Combined (n = 30)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>20.9 ±1.4</td>
<td>19-24</td>
<td>20.7 ±1.4</td>
<td>19-23</td>
<td>20.8 ±1.3</td>
<td>19-24</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>64.5 ±12.9</td>
<td>51-100</td>
<td>71.9 ±8.5</td>
<td>55-90</td>
<td>68.2 ±11.4</td>
<td>51-100</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.1 ±5.5</td>
<td>160-180</td>
<td>177.5 ±7.7</td>
<td>162-189</td>
<td>172.8 ±8.1</td>
<td>160-189</td>
</tr>
<tr>
<td>Resting HR (bpm)</td>
<td>85.3 ±16.6</td>
<td>54-119</td>
<td>79.1 ±12.4</td>
<td>65-113</td>
<td>82.2 ±14.7</td>
<td>54-119</td>
</tr>
<tr>
<td>Exercise HR (bpm)</td>
<td>168.4 ±5.7</td>
<td>158-182</td>
<td>167.8 ±6.9</td>
<td>156-186</td>
<td>168.1 ±6.2</td>
<td>156-186</td>
</tr>
<tr>
<td>Borg Scale</td>
<td>14.0 ±2.1</td>
<td>11-17</td>
<td>14.7 ±2.0</td>
<td>12-18</td>
<td>14.4 ±3.0</td>
<td>11-18</td>
</tr>
</tbody>
</table>

Exercise HR/Borg Scale recorded 15th minute exercise.
Reliability
ICC’s were calculated for mean values. Reliability was “good” for FTN (ICC = 0.94), TG (ICC = 0.98), SLS Floor (ICC = 0.85) and SLS Foam (ICC = 0.85).

Due to the high number of subjects who achieved the 30 s threshold, the SLS Floor task was not suitable as a continuous variable in a linear model and was removed from further analyses.

FTN. There was a gradual decrease (improvement) in FTN mean scores over the first three trial time points (Table 2).
TG. The data demonstrated a steady decrease (improvement) in mean TG scores over all trial time points (Table 3).
SLS Foam. The data demonstrated a significant improvement in performance between the first and second trial time points (Table 4).

Table 2  Summary data and analysis of the Finger-to-Nose task.

<table>
<thead>
<tr>
<th>Time</th>
<th>Mean ± SD</th>
<th>Comparisons</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1</td>
<td>2.86 ±0.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-2</td>
<td>2.66 ±0.38</td>
<td>T-1 vs T-2</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>T-3</td>
<td>2.49 ±0.32</td>
<td>T-2 vs T-3</td>
<td>0.0004</td>
</tr>
<tr>
<td>T-4</td>
<td>2.50 ±0.34</td>
<td>T-3 vs T-4</td>
<td>0.8393</td>
</tr>
</tbody>
</table>

Table 3  Summary data and analysis (log transformed) of the Tandem Gait task.

<table>
<thead>
<tr>
<th>Time</th>
<th>Mean ± SD</th>
<th>Comparisons</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1</td>
<td>13.61 ±2.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-2</td>
<td>13.08 ±2.84</td>
<td>T-1 vs T-2</td>
<td>0.0216</td>
</tr>
<tr>
<td>T-3</td>
<td>12.23 ±2.22</td>
<td>T-2 vs T-3</td>
<td>0.0009</td>
</tr>
<tr>
<td>T-4</td>
<td>12.09 ±2.10</td>
<td>T-3 vs T-4</td>
<td>0.6109</td>
</tr>
</tbody>
</table>

Table 4  Summary data and analysis of the Single Leg Stance (Foam) task.

<table>
<thead>
<tr>
<th>Time</th>
<th>Mean ± SD</th>
<th>Comparisons</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1</td>
<td>4.48 ±3.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-2</td>
<td>5.94 ±4.99</td>
<td>T-1 vs T-2</td>
<td>0.0284</td>
</tr>
<tr>
<td>T-3</td>
<td>5.91 ±5.54</td>
<td>T-2 vs T-3</td>
<td>0.5068</td>
</tr>
<tr>
<td>T-4</td>
<td>7.02 ±6.41</td>
<td>T-3 vs T-4</td>
<td>0.0846</td>
</tr>
</tbody>
</table>

Gender
Males (M) 2.58 ±0.32
Females (F) 2.67 ±0.32 M vs F 0.4126
There was an increase in performance from baseline in all tasks prior to exercise that continued post-exercise for FTN and TG and then plateaued (Fig. 1.). SLS did not improve post exercise but did improve 15 minutes after exercise.

DISCUSSION
The findings indicated that 15 minutes of moderate intensity exercise facilitated performance of FTN and TG tasks. The data demonstrated an improvement in performance prior to exercise in all measures, which might suggest the presence of a learning effect. Learning effects have been previously associated with the performance of SLS tasks and can reduce the reliability of performance tests.

In this study there was no evidence to suggest a significant decrease in balance performance following exercise, which is inconsistent with the findings of previous studies. Differences in exercise mode and intensity between studies might account for this.

Limitations of this study include the single measure of exercise intensity, the narrow age range of the subjects, and that the study was conducted in a laboratory setting. All these factors limit the generalisability of the results.

CONCLUSION
Current management guidelines utilise motor performance as a surrogate measure of neurological function in the assessment of concussion. The study demonstrated that moderate intensity exercise had a significant effect on these measures. These findings need to be taken into account in the assessment and management of concussion.

FIGURE 1. Absolute percentage (%) mean change from baseline (T1) for FTN, TG & SLS.
REFERENCES


What is already known on this topic

- Athletes suspected of being concussed are screened by sideline sports medicine personnel to determine appropriate medical management.
- Current concussion management guidelines utilise motor performance tasks as surrogate measures of neurological function.
- Physical activity can affect the performance of these measures.

What this study adds

- This study demonstrated that moderate intensity exercise facilitated performance of dynamic balance and coordination tasks.
- There was no evidence to suggest a significant decrease in static balance performance following exercise.
- These findings need to be taken into account in the assessment and management of sports related concussion.

Competing interests: None declared