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Changes in the timed finger-to-nose task performance following exercise of different intensities

S John Sullivan,1 Anthony G Schneiders,1 Phil Handcock,2 Andrew Gray,3 Paul R McCrory4

ABSTRACT
Objective  The purpose of this study was to determine the effect of different levels of exercise intensity on the timed finger-to-nose (FTN) task, a measure of upper limb coordination included in the Sport Concussion Assessment Tool (SCAT2).

Methods  A three-group crossover randomised design was used to investigate changes in FTN times at three levels of exercise intensity; no exercise/rest (NE), moderate intensity exercise (ME) and high-intensity exercise (HE). Heart rates and a rating of perceived exertion (Borg Scale) were recorded to verify the level of exercise intensity. Participants performed three trials of the timed FTN task: pre-exercise, post-exercise and 15 min after the cessation of exercise. Linear mixed models were used to compare FTN change scores associated with exercise.

Results  Ninety asymptomatic participants (45:54:55) aged 18–32 years completed the study. Changes in FTN scores from pre-exercise showed that the HE condition was facilitated relative to NE at post-exercise (8% faster, 95% CI 5% to 10%, p<0.001) and at post-15 (3% faster, 95% CI 1% to 6%, p=0.005). ME did not show such a facilitation following exercise (2% faster, 95% CI 0% to 4%, p=0.081 and 1% faster, 95% CI 1% to 4%, p=0.225 respectively).

Conclusions  Performance on the FTN task is enhanced by a short period of HE, and this effect persists for at least 15 min. There was no evidence of such an effect with ME.

INTRODUCTION
The recently revised Sport Concussion Assessment Tool (SCAT2) includes a measure of upper-limb coordination in the form of the timed finger-to-nose (FTN) task.1 Derived from the classic neurological assessment for dysmetria, dyskinesia and tremor, the protocol provides a global and objective measure of upper limb coordination.2 The FTN has been shown to be robust in different testing situations3 and has well-established reliability4–5 and normative data5–7.

In the sporting context, players are most likely be assessed immediately following a suspected concussive brain injury and while still recovering from the normal and possibly fatigue effects of the associated physical exertion. While there is a growing literature on the effects of exercise/fatigue on balance and on the Balance Error Scoring System8–10 in particular, only preliminary data4 have been published on how varying levels of exercise might influence the performance of the FTN task.

The purpose of this investigation was to assess the effects of different levels of physical activity on the time to perform the FTN task in asymptomatic subjects.

METHODS
Subjects
A cohort of physically active persons with no known neurological, musculoskeletal or cardiovascular condition likely to influence the results were recruited into the study which was approved by the University of Otago Human Ethics committee.

Design
A crossover randomised design had all subjects completing three levels of the exercise intervention, each level on a different day, each 1 week apart, with equal numbers randomly assigned to each of the six possible orders of exercise intensities. Sex was approximately balanced within each of the six groups. The exercise intensities were: no exercise/rest condition (NE); moderate intensity exercise (ME) and high-intensity exercise (HE). The FTN test was used three times at each of the following times; prior to exercise, immediately following exercise and 15 min following exercise. This study was part of a larger project, and further methodological details are provided elsewhere.11

Equipment
The data collection took place in a university research laboratory using a stopwatch (Oregon Scientific, Portland, Oregon) to record the FTN times, a standard cycle ergometer (Monark 818e, Stockholm, Sweden) and a cycle ergometer modified for arm cranking for the exercise interventions.

Measure
The FTN task was administered with the subject seated with their eyes open. They began the task with their right arm outstretched, with their shoulder at 90° and their index finger extended. On the command ‘go,’ they were required to touch the tip of their nose with their index finger and return to the starting position. They were instructed to repeat this five times ‘as quickly and as accurately’ as possible, and the time for the five repetitions was recorded with a stopwatch.
**Exercise intervention**

The ME had an aerobic focus and required the subject to cycle against a manually adjusted load at 60–70 rpm with a target zone set at 75–85% of their age predicted maximum heart rate (APMHR). The HE condition attempted to simulate high-intensity intermittent sports and involved 9 min of cycling as per the ME condition, followed by short (30 s) bursts of HE (>85% APMHR) alternated with bouts of moderate cycling (5 min). The final minute of exercise involved a 30 s all-out bout of upper-limb crancking followed by 30 s of slow arm crancking. The NE condition required subjects to rest. All exercise periods were of 15 min duration, and an estimate of their rate perceived exertion (RPE) using the Borg Scale\textsuperscript{12} was obtained. Heart rates (HRs) and blood lactate levels were monitored to ensure that appropriate exercise loading was attained.

**Procedures**

Following randomisation, subjects completed an exercise screening questionnaire, the Physical Activity Readiness Questionnaire,\textsuperscript{13} and provided basic anthropometric data (age, sex and body mass index (BMI)). Three trials of the FTN task were completed; prior to (pre), immediately following (post) and again 15 min after (post-15) the completion of the exercise/test conditions.

**Statistical analysis**

The data were analysed using linear mixed models with nested random effects for participant (3 days), participant-day (three times) and participant-day-time (three trials) to account for correlations between repeated measures at these levels. Models controlled for age, sex, BMI, exercise frequency, exercise on the day and trial number within each set of three trials. An order effect for the treatment orders was also included but would be retained only if statistically significant. An interaction between exercise time and trial number was similarly tested for. Differences between means were assessed using contrasts. The residuals from models were examined for skew and heteroscedasticity, and where necessary a log transformation was applied. Test–retest reliability was analysed using variance components. All statistical procedures were performed using SAS 9.1.2 (SAS Institute, Cary, North Carolina) and Stata 10.1 (Stata, College Station, Texas).

Using Stata 10.1, a sample size of 90 participants gave an 80% power to detect a difference between exercise conditions of 0.3 SD (a small effect size) assuming a correlation of at least 0.3 between repeated measures on participants using a two-sided test with $\alpha=0.05$.

**RESULTS**

The 90 subjects (45 females and 45 males) who completed the study had a mean age of 21.8 years (range 18–32) and a mean BMI of 24.4 (range 17.8–34.7). Post-exercise HRs (mean±SD) were 71±11, 163±7 and 177±11 beats per minute for the NE, ME and HE respectively; while lactate levels (mmol/l) were 2.82 (1.25) in the No exercise condition, and 2.95 (1.29) and 3.02 (1.29) in the ME and HE conditions, respectively; while lactate levels (mmol/l) were 6±0.23, 15±1.96 and 17±2.17 respectively. These markers indicate that exercise doses employed were appropriate to the study objectives. The FTN data were log-transformed (due to skew) and the geometric means presented in Table 1. Differences in change scores between the three exercise conditions with the percent-age of persons with scores of 4 s or longer included (p<0.001). The overall exercise intensity by time interaction was statistically significant (p<0.001), and differences between intensities in terms of changes over time are shown in Table 2.

There was no evidence of sex, age or BMI associations (p=0.497, p=0.721 and p=0.819 respectively). Exercise frequency and exercise on the day were also not statistically significantly associated with FTN times (p=0.833 and p=0.932). From the full linear mixed model, the proportion of variance attributable to subjects was 80.3%.

**DISCUSSION**

The results indicate an improved performance of the task following HE that continues over the recovery period where it is still facilitated relative to baseline values; whereas the pattern of facilitation for the moderate intensity condition was not statistically significant at either time point. This contrasts to our previous finding for a similar exercise load where changes were seen immediately post-exercise.\textsuperscript{4} HE had a greater facilitatory effect than ME from pre-exercise to post-exercise. These data suggest a differential response to exercise types (anaerobic/aerobic), a finding observed in measures of dynamic but not static balance.\textsuperscript{8}

The finding of an increased performance in this upper limb task, while confirmatory of our previous report,\textsuperscript{4} is diametrically opposed to that reported for measures of static balance where performance decrements for a number of variables are reported following exercise.\textsuperscript{3,5,10} The duration and time course of the facilitatory effects in this study are not clear in this study, as only one follow-up measurement was taken at 15 min postexercise. The reason for a task-specific response for the FTN and balance tasks is speculative and does suggest the need for caution in interpreting data obtained from an athlete following a period of physical activity.

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**Table 1** Geometric means (±SD) presented in seconds for the finger-to-nose test for the three exercise conditions with the percent-age of persons with scores of 4 s or longer

<table>
<thead>
<tr>
<th>Exercise condition</th>
<th>Exercise</th>
<th>Pre</th>
<th>Post</th>
<th>Post-15</th>
</tr>
</thead>
<tbody>
<tr>
<td>No exercise</td>
<td></td>
<td>3.00 (1.25)</td>
<td>2.95 (1.25)</td>
<td>2.91 (1.25)</td>
</tr>
<tr>
<td>Percentage with mean ≥4 s</td>
<td></td>
<td>10.0</td>
<td>10.0</td>
<td>8.9</td>
</tr>
<tr>
<td>Moderate intensity</td>
<td></td>
<td>2.96 (1.25)</td>
<td>2.85 (1.25)</td>
<td>2.92 (1.25)</td>
</tr>
<tr>
<td>Percentage with mean ≥4 s</td>
<td></td>
<td>8.9</td>
<td>6.7</td>
<td>6.7</td>
</tr>
<tr>
<td>High intensity</td>
<td></td>
<td>3.02 (1.29)</td>
<td>2.74 (1.26)</td>
<td>2.82 (1.25)</td>
</tr>
<tr>
<td>Percentage with mean ≥4 s</td>
<td></td>
<td>8.9</td>
<td>5.6</td>
<td>6.7</td>
</tr>
</tbody>
</table>

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**Table 2** Differences in change scores between the testing periods

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Change (%) in time</th>
<th>95% CI</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre–post HE–NE</td>
<td>−8**</td>
<td>−10 to −5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pre–post ME–NE</td>
<td>−2</td>
<td>−4 to 0</td>
<td>0.081</td>
</tr>
<tr>
<td>Pre–post HE–ME</td>
<td>−6</td>
<td>−8 to −3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pre–post 15 HE–NE</td>
<td>−3</td>
<td>−6 to −1</td>
<td>0.005</td>
</tr>
<tr>
<td>Pre–post 15 ME–NE</td>
<td>−1</td>
<td>−4 to 1</td>
<td>0.225</td>
</tr>
<tr>
<td>Pre–post 15 HE–ME</td>
<td>−2</td>
<td>−4 to 0</td>
<td>0.115</td>
</tr>
<tr>
<td>Post–post 15 HE–NE</td>
<td>5</td>
<td>2 to 7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Post–post 15 ME–NE</td>
<td>1</td>
<td>−2 to 3</td>
<td>0.592</td>
</tr>
<tr>
<td>Post–post 15 HE–ME</td>
<td>4</td>
<td>1 to 6</td>
<td>0.002</td>
</tr>
</tbody>
</table>

*Negative values indicate an increase in performance. **Statistical significance.

HE, high-intensity exercise; ME, moderate-intensity exercise; NE, no exercise/rest.
What is already known about this topic

- International consensus has seen the development of a tool (Sport Concussion Assessment Tool (SCAT2)) for the assessment of a sports concussion.
- An integral component of the SCAT2 is a measure of upper-limb coordination using the timed finger-to-nose test.
- It has been well established that moderate exercise can influence motor performance tasks including balance, which are frequently used in the assessment of a sports concussion.

What this study adds

- Exercise has a facilitatory effect on speed of performing the finger-to-nose task, a measure of upper-limb coordination.
- The higher-intensity exercise, with an anaerobic focus, was more facilitatory.
- Sports medicine professionals need to be aware of this effect when making decisions concerning the status of an athlete suspected of being concussed.

The interaction between FTN performance and levels of system arousal (inverted U-hypothesis) may suggest that a more intense and limb specific fatigue was necessary to decrease performance. While the changes recorded for the FTN task are relatively small, this may play a role in the interpretation of the test data. The mean pre-exercise values for the FTN task are comparable (2.9±1.1 and 3.0±1.2 s for the dominant and non-dominant limbs respectively) with those we have obtained previously with a physically active cohort and somewhat faster (3.56±1.1 and 3.44±1 s for the left and right limbs respectively) than those reported by Swaine et al. for the same version of the FTN test but with a possibly less physically active sample.

Although data on the FTN in persons immediately following a concussion are not currently available, values in excess of 4 s have been reported in persons following a more severe traumatic brain injury. The SCAT2 instructions suggest that a score of greater than 4 s be considered as a potential indicator (scored as a ‘0’ of a concussion. In this study, the percentage of participants who returned a score ≥4 s ranged from 10.0% to 5.6%, indicating the potential for false-positive decisions in the non-concussed population. This potential was reduced following exercise. Thus, the effect of preassessment physical activity must be considered when making decisions about a player. In particular, a ‘genuine’ score of ≥4 s could be masked by the facilitatory effects of exercise and consequently may not be an accurate representation of the neurological status of the athlete.

This study employed a rigorous design to explore the effects of exercise. Although the subjects were randomised to conditions, there was an unexplainable difference between conditions in the pretest. However, the exact time course of the changes or the duration of the exercise needed to induce them was not specifically investigated and needs further consideration. These data have highlighted the need to consider preinjury activities in interpreting FTN times in the sports situation and that the impact may be different from that recorded for other variables such as measures of balance.

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Competing interests None.

Ethics approval Ethics approval was provided by the University of Otago Ethics Committee.

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