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Research article

# The impact of physical activity on motor preparation in young adults

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## HIGHLIGHTS

- Simple and choice reaction and premotor times were prolonged in less active participants.
- Hemisphere-specific increase in contingent negative variation amplitude over higher order motor areas for the left hand simple reaction time task in more physically active participants.
- Physical inactivity in young adults may be associated with reduced motor function and cognitive processing.

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## ABSTRACT

Regular physical activity benefits brain health and function. Physical activity performed by young adults is declining. However, the influence of diminished physical activity on cognitive performance and motor preparation in young adults remains unclear. This study measured changes in behavior and brain activity during preparation and performance of simple (SRT) and choice (CRT) reaction time tasks in less and more physically active young adults. Electromyograms were obtained from left and right first dorsal interossei muscles. Midline and hemisphere-specific electroencephalograms were analyzed from frontal and central scalp regions in 11 less- and 11 more-active participants. Physical activity level was assessed by questionnaire (IPAQ). Reaction and premotor times were slower for SRT and CRT tasks in less active participants. No statistically significant difference in contingent negative variation (CNV) amplitude was present between groups. Hemisphere-specific CNV amplitude over frontal scalp regions was evident for both less and more active participants for right hand SRT, whereas only the more active group showed hemisphere-specific CNVs for left hand SRT. Decreased levels of physical activity in young adults may be detrimental for cognitive processing and motor function measured by reaction time and changes in brain activity.

## 1. Introduction

Participation in regular physical activity and exercise has a beneficial impact on the health and function of most physiological systems, including the brain [1]. Recent reports indicate that the amount of physical activity performed by young adults is declining [2]. Previous literature indicates that reaction time, a measure of cognitive processing speed, is slower in physically inactive young adults. [3–7]. However, the influence of less physical activity on changes in brain activity during cognitive processes and motor preparation in young adults is limited and equivocal.

Event related potentials (ERPs) have been used to examine the relationship between exercise and cognitive performance. Stimulus discrimination and/or processing components of the ERP, such as the N200 and P300, are enhanced in active compared with inactive individuals [4,8]. The most notable enhancements are reported for older adults, but evidence indicates that similar benefits are observed in young adults [4,5,8]. However, speed of related cognitive processing and motor preparation has received little attention.

The amplitude of the negative slow wave cortical potential, termed contingent negative variation (CNV), reflects change in brain activity specific to movement preparation [9]. The link between exercise and brain activity in young adults remains unresolved. One source of inconsistency is the different electrode configurations used to assess cognitive processing and motor preparation. CNVs recorded along the nasion-inion midline (e.g., Fz, Cz) reportedly show an early component related to higher cognitive processes and a late component associated with motor prepara-

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tion [10]. Arito and Oguri [3] demonstrated that early and late components of the CNV from frontal (Fz) and central (Cz) scalp regions were greater in more active young adults for Go/No-Go tasks. In contrast, CNV amplitude recorded over Fz for a more cognitively demanding task (Sternberg working memory task with speed instructions) was larger in inactive young adults compared with active [11]. These divergent findings may, in part, be related to task instructions. However, CNVs recorded from midline electrodes cannot discriminate changes in brain activity specific to left and right hand performance. The inability to differentiate hemispheric activity masks whether hemisphere-specific contributions exist in CNVs recorded from scalp locations providing information about higher cognitive (frontal) and motor preparatory (central) processes [12].

We examined cognitive processes performed by less and more physically active young adults by measuring changes in hemisphere-specific brain activity during preparation for simple and choice reaction time tasks. We hypothesized that reaction time to discrete responses would be prolonged in less active individuals. We also hypothesized that the change in CNV amplitude during movement preparation would be smaller in less active individuals.

## 2. Material and methods

### 2.1. Participants

Participants were 24 young adults with no known history of peripheral or neurological impairment. Data were excluded from two participants who did not perform the task correctly. Data were analyzed from 22 participants (10 females, 12 males; 22 ± 1 years; range 18–23 years). All participants were right-handed (Edinburgh Handedness Questionnaire [13]), median Laterality Quotient (LQ) of 0.81 (range 0.4–1.0). Participants were assigned to “more active” (6 females and 5 males) or “less active” (4 females and 7 males) groups based on assessment using the long version of the International Physical Activity Questionnaire (IPAQ). This questionnaire has produced reliable and repeatable measures of physical activity in multiple sociocultural backgrounds and is comparable to objective assessment by accelerometer [14]. To reflect physical (aerobic) fitness more accurately in the self-reported IPAQ score, participants were asked to focus on leisure-time physical activity, with an emphasis on vigorous physical activity such as running and cycling [15]. Overall, less active participants performed no vigorous physical activity and no more than one session of moderate physical activity for 50 min in a typical week. All participants gave informed consent prior to participation in a single session. (University of Auckland Human Participant Ethics Committee UAHPEC 015300).

### 2.2. Experimental procedure

Participants were seated comfortably facing the experimental apparatus [for detailed description see 16]. Forearms and wrists were pronated and elbows flexed at ~90°. The dorsal surface of each index finger rested on the proximal end of the corresponding response key activated by finger flexion. Movement was detected by a force transducer beneath each response key. Force was digitized at 1 kHz with a BrainAmp ExG (Brain Products Inc, GmbH, Munich, Germany) and recorded onto a computer for offline analysis using Brain Products Software (Brain Products Inc, GmbH, Munich, Germany).

Surface electromyography (EMG) was recorded from the first dorsal interosseous muscle (FDI) of each hand using 10-mm-diameter Ag-AgCl surface electrodes (Ambu Blue Sensor Paediatric NS, Ballerup, Denmark) placed ~2 cm apart in a belly-tendon montage. A ground electrode (3 M Canada) was placed on the dorsum of each hand. EMG signals were amplified (resolution of 0.1 $\mu$V per bit, x1500), filtered (DC-1000 Hz; 50 Hz notch filter applied), digitized at 1 kHz with a BrainAmp ExG (Brain Products Inc, GmbH, Munich, Germany) and recorded onto a computer for offline analysis using Brain Products Software (Brain Products Inc, GmbH, Munich, Germany).

Surface electroencephalography (EEG) was recorded with Ag-AgCl electrodes using a Fast’n Easy Cap (FE32-#-BA, Brain Products Inc, GmbH, Munich, Germany). EEG data were recorded bilaterally from frontal (FC1, FC2), central (C3, C4) and occipital (O1, O2) electrodes according to the 10–20 system [17] referenced to linked mastoids (offline) and FCz (online). A ground electrode was located at AFz. In addition, EEG data were recorded from the midline electrode sites of Fz (frontal) and Cz (central). Eye position (electrooculography; EOG) was recorded using two pairs of electrodes in vertical (below the left orbit) and horizontal (outer canthus of the left eye) directions. Surface EEG and EOG signals were amplified (resolution of 0.5 $\mu$V per bit; x500), filtered (DC-200 Hz; 50 Hz notch filter applied), digitized at 1 kHz with a 32-channel BrainAmp DC (Brain Products Inc, GmbH, Munich, Germany) and recorded onto a computer for offline analysis using Vision Analyzer2 (Brain Products Inc, GmbH, Munich, Germany). All electrode impedances were below 5 k$\Omega$.

### 2.3. Task

Participants performed simple and choice reaction time tasks with their left or right index finger. Each trial began with a central red warning light (fixation) followed by a precue (500 ms) signalled by the illumination of blue diodes embedded within each response key then a foreperiod (1500 ms) before the imperative “go” stimulus (response key illuminated for 100 ms). For simple reaction time (SRT) trials, the key to be pressed (left or right index finger) was signalled by the precue and provided complete information for participants to prepare the appropriate response during the foreperiod. For choice reaction time (CRT) trials, both left and right response keys were illuminated during the precue, thus the correct response remained unspecified until the imperative stimulus occurred.

Following explanation of the task, each participant completed one block of 60 simple and choice familiarization trials. For data collection, participants completed four pseudo-randomized blocks of 60 trials (204 trials in total) with trial types equally distributed across each block (15 SRT left, 15 SRT right, 15 CRT left, and 15 CRT right). Catch trials (precue was not followed by a stimulus) were randomly distributed in each block (10% of total trials) to reduce anticipatory responses. A 2-min rest period was provided between each block and participants were reminded of task requirements during this interval.

### 2.4. Data analysis

#### 2.4.1. Data reduction

A global DC detrend correction was applied to all data. The EMG data were band-pass filtered (10–500 Hz) and rectified. The EEG data were re-referenced to mathematically averaged mastoids (ML, MR) and low pass filtered (30 Hz). Data were epoched from 500 ms before the precue to 1000 ms after the imperative stimulus (total epoch duration of 3500 ms) and normalized to baseline (500 ms before precue onset).

#### 2.4.2. Behavioral analysis

Reaction time was calculated as the time between imperative stimulus and movement initiation (first positive force inflection of the response key). Premotor time, a measure indexing central processing delay, was the time between stimulus onset and the acute change from baseline EMG (greater than 2SD). Motor time (duration