Effects of Mental Fatigue Induced by Social Media Use on Volleyball Decision-Making, Endurance, and Countermovement Jump Performance

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EFFECTS OF MENTAL FATIGUE INDUCED BY SOCIAL MEDIA USE ON VOLLEYBALL DECISION-MAKING, ENDURANCE, AND COUNTERMOVEMENT JUMP PERFORMANCE

SHORT TITLE: REPEATED MENTAL FATIGUE AND VOLLEYBALL

Abstract

Objective: The objective of this study was to analyze the chronic effects of smartphone use before each training session on decision-making, countermovement jump (CMJ) and endurance performance in young volleyball athletes. **Material and Methods:** The twenty-four young male volleyball athletes underwent the six weeks of experiment. The athletes were pair-matched according to decision-making performance and, then, randomized in block in two groups: control (CON) and smartphone (SMA). Before each training session, the CON group watched TV for 30-min and SMA group used social network smartphone apps for 30-min. **Results:** It was revealed a group x time interaction for attack ($p = 0.03$) and passing decision-making ($p = 0.02$). Only the CON group improved the attack ($p = 0.03$) and passing decision-making ($p = 0.02$). It was not revealed a group x time interaction for CMJ ($p = 0.91$). Both groups improved the CMJ ($p = 0.01$). None of the groups improved the endurance performance ($p = 0.56$). **Conclusions:** We conclude that 30-min of frequent use of smartphone apps prior to training sessions during 4-weeks of volleyball training may be responsible for impairment in decision-making performance in male young volleyball athletes.

Keywords: chronic fatigue, game analysis, volleyball, athletes, team sport.

Introduction

Volleyball is one of the five most practiced sports in the world.[1] It is an intermittent team sport characterized by fast and skillful actions (service, pass, attack, block, and defense), with high levels of unpredictability.[2] Thus, volleyball players must present highly developed cognitive, physical, and technical abilities to succeed.[3]

Scientific literature has shown that the countermovement jump (CMJ) is a reliable measure to assess lower-limb anaerobic performance in athletes[4-6] because of its high correlation with muscular strength and sprint performance in athletes.[7] In volleyball, the CMJ performance is vital since athletes perform hundreds of jumps during a match.[8] However, because of short intervals, recovery capacity is also critical.[3] Interestingly, muscular recovery capacity is associated with endurance performance,[9] and a higher endurance capacity might speed up muscle recovery in athletes.[10] Although it is well-established that appropriate neuromuscular and endurance abilities are required,[11] fast and accurate decision-making ("what to do") and technique ("how to do") are decisive for success in all team sports.[2]

Decision-making refers to the human brain's ability to perceive relevant information from the environment, correctly interpret, and then select the appropriate motor response,[12] which is considered essential in team sports.[13-14] According to Murgia et al.[15], decision-making relies on cognitive processes such as visual perception, attention, anticipation, and memory. In a volleyball match, the athlete must quickly anticipate and react to fast-changing situations (i.e. block and defense movements) to make the best decision. Volleyball passing decision-making is crucial because of the pass must reach the setter's hand and allow better attack possibilities, considering the number of opposing blockers and decreasing the time between the setting and attack.[2]

Also, attack decision-making is essential since attack might result in a direct point and lead to victory in elite categories.[16] Thereby, considering the amounts of information given to athletes at every moment and the metacognitive components involved in decision-making, it is likely that volleyball athletes fail to make the best decision if any cognitive process is compromised (i.e. mentally fatigued athlete).[14, 17]

A Mentally fatigued athlete is in a psychobiological state induced by long periods of high cognitive activity that causes tiredness and lack of energy.[18] It is regulated by neurophysiological mechanisms such as an increase of theta wave in prefrontal cortex,[19] augmentation of adenosine concentration in the cingulate anterior cortex,[20] inhibition of dopamine neurotransmission receptor in the brain,[21] reduction of brain glucose,[20] and a reduction of brain oxygenation[22] triggered by highly demanding cognitive activity that involves sustained vigilance and attention for a prolonged period. Thereby, driving a car or using social networks on smartphones might produce mental fatigue.[21, 23]

Previous studies showed that mental fatigue did not affect performance in high-intensity and short-duration tasks.[24-25] However, endurance performance might be impaired by highly demanding cognitive activity for at least 30-min.[26-29] Studies also demonstrated that mental fatigue impairs decision-making performance in team sport athletes.[14, 17, 23] However, the aforementioned studies tested sports other than volleyball (e.g., soccer and cycling) and it is unknown whether the frequent use of social networks on smartphones before training sessions impairs physical (e.g., CMJ and endurance) and cognitive (e.g., decision-making) performance gains in athletes chronically exposed to mental fatigue.

Thus, the objective of this study was to analyze the chronic effects of smartphone use before each training session on decision-making, CMJ, and endurance performance in young volleyball athletes. Considering the limited scientific literature about mental fatigue and sport performance,[21, 29] some hypotheses were created: 1) using smartphone for prolonged periods before training sessions causes detrimental effects on decision-making performance; 2) using smartphone for prolonged periods before training sessions leads to detrimental effects on endurance performance and; 3) using smartphone for prolonged period before training sessions does not affect CMJ performance.

Materials and methods

Participants

Twenty-four young male volleyball athletes of national level (means and SDs of 15.7 ± 0.6 years; 1.85 ± 0.06 m; 81.3 ± 6.9 kg; for age, height and body mass, respectively) volunteered and participated in the study. They had a training frequency of 4.9 ± 0.2 sessions/week (10.3 ± 0.8 h/week) and training experience of ~ 3.4 years (national and regional tournaments). The participants were non-smokers and free from cardiovascular, visual, auditory, and cognitive disorders. Experimental procedures, risks, and benefits were explained before collecting their written consent form signature. The procedures were previously approved by a local Ethics Committee and performed according to the Declaration of Helsinki. Written informed consent of guardians and written informed assent of young participants were obtained before participation.

Experimental design

It is a randomized and experimental investigation with parallel contrast groups performed with young male volleyball athletes. The participants underwent the six weeks of experiment (1-week = baseline assessment; 4-weeks = experimental training sessions [five sessions per week]; and, 1-week = post-experiment assessment) (Figure 1). Every single athlete performed 20 training sessions that involved physical, technical, and tactical skills (Table 1). The athletes pair-matched according to decision-making performance (attack and pass) and randomized in blocks of two groups, control (CON, n = 12) and smartphone (SMA, n = 12). Before each training session, the CON group watched TV for 30-min (20 different documentaries about Olympic Games) and the SMA group used social networks on smartphones (Facebook®, Instagram®, and Whatsapp®) for 30-min. After a 3-min interval, the training session initiated.

We measured the decision-making (attack and pass), countermovement jump (CMJ), endurance performance, Stroop Task (accuracy and response time), and subjective mental fatigue before (baseline) and after (post-experiment) the four weeks of intervention (20 training sessions). Also, we adopted an interval of 24-48 h between in each test in both baseline and post-experiment.

For decision-making performance analysis, the athletes participated in a simulated match (three sets of 25 points), adopting the official volleyball rules. We recorded matches using a CANON® camera (SX60 model, Yokohama, Japan) for further analysis of attack and passing decision-making using the Game Performance Analysis Instrument (Memmert & Harvey, 2008). The athletes performed the matches in the same experimental group with the opponents under the same treatment conditions (CON or SMA), as proposed in the scientific literature.[21, 23]

Experimental procedures are illustrated in Figure 1. The participants abstained from any physical exercise and alcohol ingestion 24-h before testing during the six weeks of the experiment as well as abstained from caffeine at least 3-h before each training session.

Table 1

Figure 1

Interventions

We recommended the athletes to ingest fluid *ad libitum* up to 2 h before each training session and to avoid smartphones 2 h before each training. The CON group watched videos about Olympic Games for 30-min on an 84-inch screen (smartphone free room). The SMA group used social networks on smartphones (WhatsApp®, Facebook®, and Instagram®) for 30-min. We supervised the participants to ensure the athletes only used social networks (and not games, for example). The experimental groups (CON and SMA) remained in different rooms while using smartphones or watching videos. We forbid the participants to talk to each other during the intervention.

Measurements

Decision making-performance (attack and pass)

We measured decision-making during the simulated matches. The participants played three sets of 25 points with a 3-min interval following the official rules of volleyball. If a team won the two first sets, the match continued. The opponents were in the same intervention (CON or SMA) and the team (six athletes) remained the same in baseline and post-experiment. The entire match was recorded with a CANON® camera (SX60 model, Yokohama, Japan). The analysis and categorization of actions were based on the GPAI.[30] Memmert and Harvey[30] highlight that the GPAI evaluates the appropriate decisions about what to do. The attack and pass decision-making components were assessed. Thus, appropriate attack decision-making was considered when the attempted attack was directed to a vulnerable region of the opponent's court or explored the block. The appropriate passing decision-making occurred when the intention (e.g., the intention of sending the ball to a teammate) was to direct the ball to the setter's hands or to pass to an unmarked striker (e.g., without the presence of the opposing block). Any other intent to attack or pass was considered inappropriate. The obtained data (videos) were analyzed using an open-license video analysis software (Kinovea 0.8.15 for Windows).

The decision-making index (DMI) was calculated according to the formula below, following the instructions suggested by Memmert and Harvey[30]. Two experienced researchers analyzed the match actions (they watched the videos carefully on an 84-inch tv screen) and categorized it as appropriate or inappropriate. The investigators who reviewed the video footage and categorized decision-making actions were blinded to the experimental treatments [CON and SMA] to decrease biases. The main researcher calculated the coefficient of agreement between the two specialists for the DMI (Baseline; attack: kappa = 0.96, p = .001; pass: kappa = 0.99, p = .001; Post-experiment: attack: kappa = 0.94, p = .001; pass: kappa = 0.97, p = .001) and the values were satisfactory.

$$\text{DMI} = \frac{Aa}{Aa + Ia} x\ 100$$

Aa = appropriate actions

Ia = inappropriate actions

Considering that a volleyball game is not a controlled environment varying in type and actions, the number of attacks and passes was not equivalent among the athletes. Also, the number of attacks and passes was statistically controlled (inserted as a covariate) on the analyses.

Countermovement jump (CMJ)

An electronic contact jump mat (Hidrofit®, Jump System, Belo Horizonte, Brazil) was used to analyze the CMJ height. Each participant performed three attempts with 30-s interval among trials and the best attempt was retained for analysis. The participants performed the CMJ with hands on the waist and no restrictions on the knee angle during the eccentric phase of the jump. Also, we instructed the participants to maintain the legs in a straight position during the flight and land phases. The participants were familiar with the test before the beginning of the investigation. In the present study, the intraclass correlation coefficient (ICC) was 0.99 ($IC_{95\%}$ = 0.97 to 0.99) and 0.98 ($IC_{95\%}$ = 0.95 to 0.99) for CMJ in baseline and post-experiment, respectively, indicating good reproducibility of the test performance.

Endurance performance

We used the Yo-Yo intermittent Recovery Level 1 to analyze endurance performance.[31] Each athlete ran as long as possible a distance of 20 meters (round trip) delimited by cones. The rest period between each round trip was 10 seconds, as recommended by Bangsbo et al.[31] The test finished when the athlete gave up or was unable to keep up with the pace determined by the test, executing two errors on the same stage. The participants were familiar with the test before the beginning of the investigation. In the present study, the ICC was 0.96 ($IC_{95\%}$ = 0.93 to 0.99) and 0.92 ($IC_{95\%}$ = 0.91 to 0.99) in baseline and post-experiment, respectively, for Yo-Yo intermittent Recovery Level 1.

Inhibitory control

The Stroop task[32] assessed inhibitory control and selective attention, both considered components of the cognitive function. The participants answered the word color or according to its name, since the color of the words might be different from what is typed (e.g. the word “blue” might show up in “red” color, the word “green” in “blue”, and so on). A stimulus of 30 words with 200 ms of the interval was provided between the response and a new stimulus.

Moreover, the stimulus did not fade from the screen until any response was given. Stimuli vary between congruent (word and color have the same meaning), incongruent (word and color have a different meaning), and control (colored rectangle with one of the colors of the test: red, green, blue, and black). The keys D (red), F (green), J (blue), and K (black) were pressed to answer the questions. The stimulus disappeared when the answer was correct, and then a new one was set. An X showed up on the screen in case of incorrect answers, and a new stimulus showed up.

We collected the accuracy of the correct answers and response time at the end of the test and the evaluator was blind for the assessments and had previous training for the test. We applied the tests on a full-HD screen (1800 × 1260 pixels) laptop (MacBook Pro, A1502 model, USA) and the ICC and coefficient of variation (CV) were used to determine the reliability of accuracy (ICC = 0.91, CV = 4.2%) and response time (ICC = 0.95, CV = 6.3%) in baseline and post-experiment [accuracy (ICC = 0.93, CV = 3.8%) and response time (ICC = 0.96, CV = 5.2%)].

Subjective MF

We assessed the subjective rating of mental fatigue using the 100 mm Visual Analogue Scale as previously adopted.[19] This scale has two extremities anchored from 0 (none at all) to 100 (maximal). We presented no other information on the Visual Analog Scale. We required the participants to answer "How mentally fatigued you feel now?" and oriented them to perform a horizontal line throughout the 100 mm scale according to their perceived status. To quantify the values, we measured the millimeter distance from the 0 to the end of the line indicated by the participant. The ICC was 0.97 ($IC_{95\%}$ = 0.94 to 0.99) and 0.97 ($IC_{95\%}$ = 0.92 to 0.98) for VAS in baseline and post-experiment, respectively.

Biologic maturation

We evaluated biological maturation by somatic maturation. Weight, stature, and trunk-head height were measured. Leg length was obtained by the difference between stature and trunk-head height. We used these measures, along with the chronological age, in an equation established by Mirwald et al.[33], which estimates the age of peak growth rate in stature. Since scientific findings have indicated the influence of biological maturation on sport performance variables,[34] we decided to control (statistically) the age of peak growth rate in stature in this study.

Internal training load

We quantified the internal training load by the rate of perceived exertion of the session (RPE-session).[35] After 30 min of each training session, the athletes answered the following question: "How was your training?". We asked the athletes to demonstrate the intensity perception of the session from the 10-point Borg scale (0 = rest to 10 = maximum effort), according to the method developed by Foster et al.[35] The product of the values demonstrated by the RPE scale and the total time in minutes of the training session was calculated expressing the internal load of the training in arbitrary units (A.U.). The weekly internal training load was obtained from the sum of daily internal training loads. We calculated the total internal training load of four weeks from the sum of weekly internal training loads. The athletes were familiarized with the session-RPE method for 30 days before the beginning of the investigation.

Statistical analysis

The Shapiro Wilk test evaluated data distribution. The Levene test assessed homoscedasticity. The two-way ANOVA analyzed group (CON vs. SMA) vs. time (baseline-vs post-experiment) interaction for decision-making (attack and pass), CMJ, inhibitory control (accuracy and response time), subjective mental fatigue, and endurance performance. The biologic maturation was inserted as a covariate in decision-making (attack and pass), CMJ, Stroop task (accuracy and response time), subjective mental fatigue, and endurance performance. The number of attacks and passes during the simulated match was inserted as covariate in decision-making (attack and pass) analysis. The independent t student compared the internal training load between CON and SMA groups. Also, the effect size (ES) at the baseline versus post-experiment and CON vs. SMA groups revealed eventual practical differences. We applied the following criteria according to the Cohen[36] guidelines for highly trained participants: ES < 0.2 = trivial, 0.2 ≤ ES < 0.5 = low, 0.5 ≤ ES < 0.8 = moderate, and ES ≥ 0.8 = large. We processed data in the GraphPad Prism Software Version 8.0 (California Corporation®, USA) with a significance level of 5%.

Results

Decision-making performance

We found a group x time interaction for attack decision-making performance (Figure 2; $F_{(4, 20)} = 4.98$; $p = 0.03$). The findings showed no group effect ($F_{(2, 22)} = 0.39$; $p = 0.39$; ES = 0.13; ES trivial), but a time effect ($F_{(2, 22)} = 3.45$; $p = 0.04$; ES = 0.36; ES low) for attack decision-making performance was observed. Only the CON group improved the attack decision-making performance ($p = 0.02$).

We found group x time interaction for passing decision-making performance (Figure 2; $F_{(4, 20)} = 5.69$; $p = 0.02$). The findings showed no group effect ($F_{(2, 22)} = 0.08$; $p = 0.77$; ES = 0.08; ES trivial), but a time effect ($F_{(2, 22)} = 6.88$; $p = 0.01$; ES = 0.42; ES low) for passing decision-making performance was observed. Only the CON group improved the passing decision-making performance ($p = 0.01$).

Figure 2

CMJ performance

We found no group x time interaction for CMJ performance (Figure 3; $F_{(4, 20)} = 0.01$; $p = 0.91$). The findings showed no group effect ($F_{(2, 22)} = 0.50$; $p = 0.48$; ES = 0.04; ES trivial), but demonstrated a time effect ($F_{(2, 22)}$ = 5.37; p = 0.03; ES = 0.35; ES low) for CMJ performance. Both groups (CON and SMA) improved the CMJ performance (p = 0.01).

Endurance performance

We found no group x time interaction for endurance performance (Figure 3; $F_{(4, 20)}$ = 0.05; p = 0.81). The findings showed no group ($F_{(2, 22)}$ = 0.33; p = 0.56; ES = 0.06; ES trivial) or time effect ($F_{(2, 22)}$ = 0.29; p = 0.59; ES = 0.10; ES trivial) for endurance performance.

Figure 3

Inhibitory control

We found no group x time interaction for accuracy ($F_{(4, 20)}$ = 0.00; p = 0.99). The findings showed no group ($F_{(2, 22)}$ = 0.82; p = 0.37; ES = 0.07; ES trivial) or time effect ($F_{(2, 22)}$ = 0.15; p = 0.69; ES = 0.03; ES trivial) for accuracy.

We observed group x time interaction for response time (Figure 4; $F_{(4, 20)}$ = 8.79; p = 0.001). The findings showed no group effect ($F_{(2, 22)}$ = 0.83; p = 0.37; ES = 0.09; ES trivial), but demonstrated a time effect ($F_{(2, 22)}$ = 3.10; p = 0.04; ES = 0.32; ES low) for response time. Only the CON group improved the response time (p = 0.01).

Subjective MF

We found group x time interaction for VAS (Figure 4; $F_{(4, 20)}$ = 5.01; p = 0.03). The findings showed no group ($F_{(2, 22)}$ = 2.85; p = 0.10; ES = 0.17; ES trivial), but time effect ($F_{(2, 22)}$ = 3.78; p = 0.04; ES = 0.22; ES low) for VAS was observed, with increase only for SMA group (p = 0.01).

Figure 4

Internal training load

We found a difference for internal training load between experimental groups ($t_{(2, 22)}$ = 2.84; p = 0.01; ES = 0.62; ES moderate). CON group demonstrated lower internal training load than SMA group (p = 0.01).

Discussion

The objective of this study was to analyze the chronic effects of social networks on smartphones before training sessions on decision-making, CMJ, and endurance performance in young volleyball athletes. The main results showed the frequent use of smartphones before training sessions for four weeks compromised the decision-making performance gains. However, the use of social networks presented no effect on endurance or CMJ performance. Thereby, our hypothesis was partially confirmed. To the best of the authors' knowledge, this is the first study to investigate the frequent use of social networks on smartphones on cognitive and physical performance in team sports players.

Regarding the attack and passing decision-making performance, our findings showed improvements in cognitive components only in the CON group after four weeks of the training intervention. On the other hand, the use of social networks on smartphones inhibited decision making improvements in the SMA group (Figure 2). The use of social networks on smartphones for at least 30-min was able to induce MF in soccer athletes.[23] To date, none studies had investigated the chronic effects of social networks on smartphones on team sports performance, making difficult a direct comparison. However, our findings are aligned to those investigations about the acute effects of mental fatigue on decision-making performance in male soccer athletes.[17, 23]

It seems that tasks with high cognitive demand for prolonged periods (e.g., reading, writing and speaking) might induce mental fatigue and impair the athlete's brain ability to extract information from the environment. Thus, the athletes that often use smartphones before training sessions, mainly the tactical or game simulated ones, might have their chronic cognitive adaptations (e.g., improve executive functions [inhibitory control, memory, and cognitive flexibility]) impaired. However, it is necessary to conduct more studies to confirm this phenomenon.

Concerning CMJ, both experimental groups (CON and SMA) improved their performance after four weeks of training, corroborating the scientific literature in the investigated sport.[4] However, the results did not reveal any chronic effect of social networks on smartphones on CMJ performance (Figure 3). These findings are supported by previous researches[24-25] of mental fatigue and high-intensity and short-duration physical efforts. The physiological mechanisms that regulate performance during high-intensity exercises are peripheral[25] whereas in mental fatigue they are central.[19] Thereby, it is likely that mental fatigue induced by smartphones presents no chronic effect on CMJ in athletes.

Concerning endurance performance, the results of the present study showed no differences between experimental groups. This somewhat differs from other studies[26-28] that have demonstrated mental fatigue cause an acute detrimental effect on endurance performance in humans. The mechanisms that regulate the endurance performance are central, the inhibitory control is responsible by the RPE on endurance events or time trials[25] and is regulated by the anterior cingulate cortex and pre-frontal cortex.[19] Perhaps, considering the brain mechanisms of mental fatigue[21] are similar to the ones that regulate endurance performance,[21, 29] induced mental fatigue before training sessions could inhibit endurance performance improvement in the long-term.

It is reasonable to assume that volleyball is a sport of low aerobic demand once the game actions last less than 10 seconds with approximately 15 seconds interval between successive points.[3] Thus, none effect was observed due to a lack of interest to improve endurance in volleyball players. However, other chronic investigations are necessary to confirm this hypothesis, especially in sports that require substantially more aerobic endurance performance (e.g., long-distance runners).

The results of inhibitory control showed no differences between baseline vs. post-experiment or between groups for accuracy. However, the CON group improved in response time whereas the SMA group remained similar to baseline. These results might be explained by subjective mental fatigue analyzed by the visual analog scale that increased for SMA and but remained the same for the CON group. Acute studies demonstrated impaired response time[14] or increased subjective mental fatigue after high cognitive demand for a prolonged period,[17, 19, 28] without changing the accuracy of inhibitory control.[23] Mentally fatigued athletes seem to compensate accuracy in the inhibitory control performance by reducing processing information speed, resulting in longer response time. Considering the volleyball practical context, the mentally fatigued athlete might take longer for processing information from the environment. Hence, due to the speed of game actions, a slower capacity to process environmental information might impair performance.

Regarding the internal training load, the results indicated higher values for SMA than the CON group. These findings corroborate other studies.[14, 23, 28] Mentally fatigued athletes show higher RPE during and after training sessions.[18, 26] It seems that athletes with higher internal training load show greater vulnerability for neuromuscular injuries.[9, 37] So, it is possible that athletes with chronic mental fatigue show higher susceptibility to neuromuscular injuries. Further studies are necessary to analyze this hypothesis.

Although the present study presented novel and important findings, some limitations must be mentioned. Theta wave in the electroencephalogram (EEG), a mental fatigue indicator, was not measured due to the lack of an electroencephalogram to analyze brain wave amplitudes (alpha and theta) at rest and after mental fatigue induction. Therefore, we recommend future investigations that include EEG to demonstrate mental fatigue via theta band or pupil dilation (e.g., eye-tracking system) to analyze cognitive effort during smartphone use.

Conclusions

We conclude that 30-min of frequent smartphone use before volleyball training sessions during four weeks causes mental fatigue (increase in subjective mental fatigue and Stroop's response time) and might impair decision-making performance (attack and passing), although endurance and the CMJ performance remained similar in male young volleyball athletes. Therefore, the results suggest that coaches should control smartphone time exposure in young volleyball athletes before training sessions.

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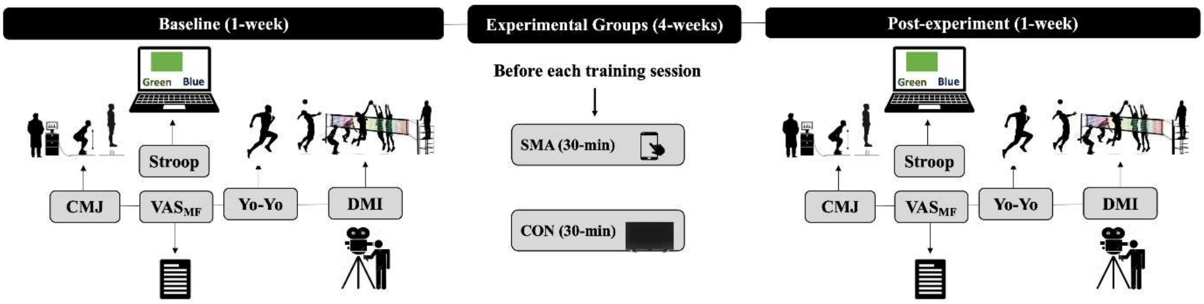
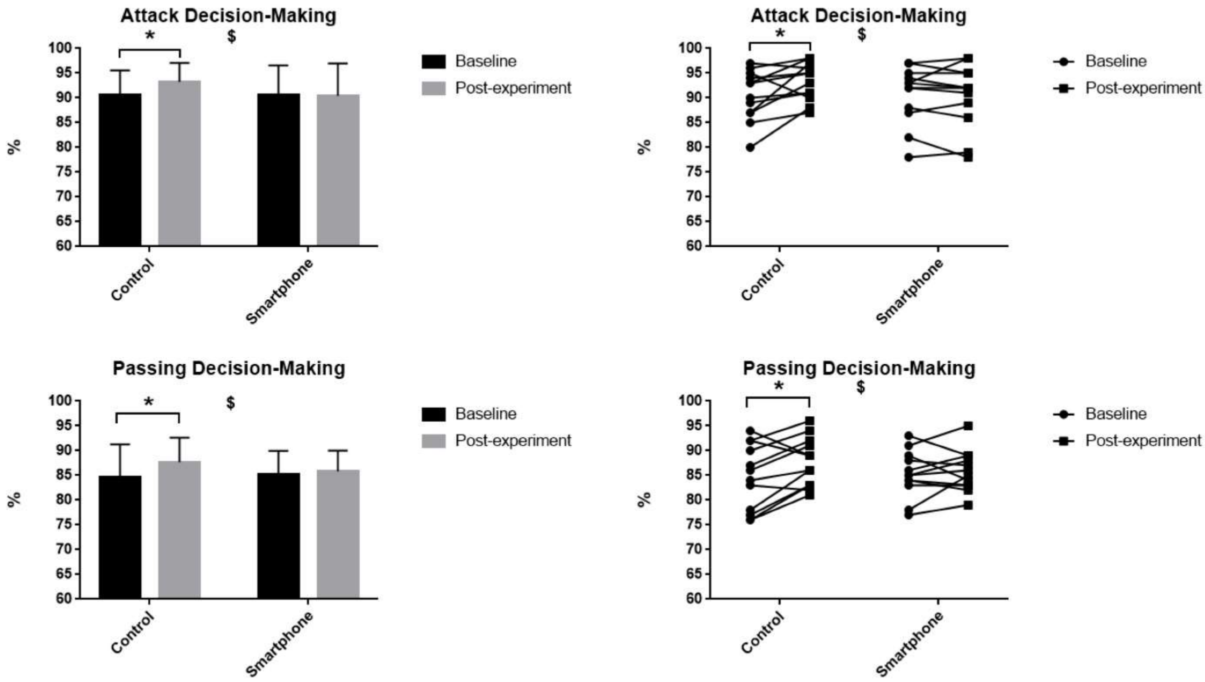
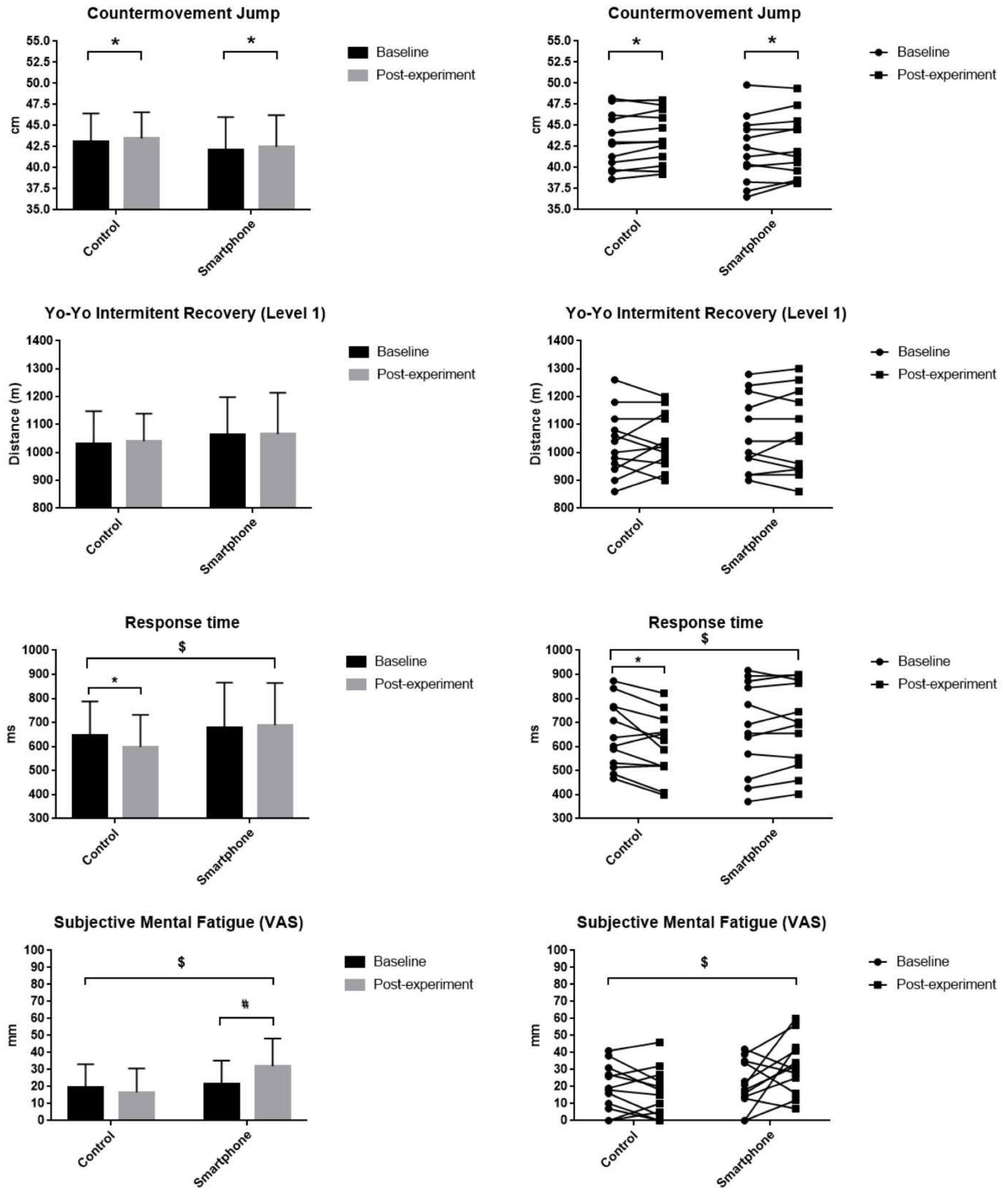
Figures.


Baseline (1-week)
Experimental Groups (4-weeks)
Post-experiment (1-week)
Before each training session
SMA (30-min)
CON (30-min)
Green Blue
Stroop
CMJ
VAS$_{MF}$
Yo-Yo
DMI


Attack Decision-Making
Passing Decision-Making
%
Control
Smartphone
Baseline
Post-experiment
*
$


Countermovement Jump
cm
Baseline
Post-experiment
Control
Smartphone
*
Yo-Yo Intermitent Recovery (Level 1)
Distance (m)
Response time
ms
$
*
Subjective Mental Fatigue (VAS)
mm
#