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Effect of HIIT on cognitive and physical performance

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KEYWORDS
HIIT;
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Abstract There is a lot of evidence indicating that exercise has a short-term positive effect on cognitive performance. Results have found contrasting findings as whether what is the optimal intensity to maximise this effect. High-intensity interval training (HIIT) has increased as a choice for both sport and health benefits. The purpose of this study was to determine the effects of HIIT on physical, reaction time and cognitive performance. Forty-four recreationally active university students (aged 18–25 years) performed the following tests before and immediately after an acute high-intensity interval training bout: the Victoria Stroop test, Reaction Time test and Countermovement Jump test. A dependent sample t-test was conducted with statistical significance set at $p \leq 0.05$. The results of the study was that there were significant improvements in Stroop test timing ($p = 0.001$) and a significant decrease in the number of errors ($p = 0.040$). Counter movement jump performance decreased slightly but not significantly ($P = 0.170$). Performance in both reaction time tests improved but not significantly (visual: $p = 0.100$; auditory: $p = 0.16$) To conclude, researchers found that HIIT had a positive effect on cognitive performance without significantly compromising physical performance in the short-term.

PALABRAS CLAVE
HIIT;
Cognición;
Tiempo de reacción;
Salto de contramovimiento

Efecto de HIIT en el rendimiento cognitivo y físico

Resumen Hay muchas pruebas que indican que el ejercicio tiene un efecto positivo a corto plazo sobre el rendimiento cognitivo. Los resultados han encontrado hallazgos contrastantes sobre cuál es la intensidad óptima para maximizar este efecto. El entrenamiento a intervalos de alta intensidad (HIIT, por sus siglas en inglés) ha aumentado como una opción tanto para los beneficios deportivos como para la salud. El propósito de este estudio fue determinar los efectos del HIIT en el tiempo de reacción físico y el rendimiento cognitivo. Cuarenta y cuatro estudiantes universitarios (de 18 a 25 años de edad) realizaron las siguientes pruebas antes e inmediatamente después de un episodio agudo de entrenamiento a intervalos de alta intensidad: la prueba Victoria Stroop, la prueba Reaction Time y la prueba Countermovement Jump.

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Se llevó a cabo una prueba t de muestra dependiente con significación estadística establecida en $p \leq 0.05$. Los resultados del estudio fueron que hubo mejoras significativas en el tiempo de la prueba de Stroop ($p = 0.001$) y una disminución significativa en el número de errores ($p = 0.040$). El rendimiento del salto de contramovimiento disminuyó ligeramente pero no significativamente ($P = 0{,}170$). El rendimiento en ambas pruebas de tiempo de reacción mejoró pero no significativamente (visual: $p = 0{,}100$; auditivo: $p = 0{,}16$). Para concluir, los investigadores encontraron que el HIIT tuvo un efecto positivo sobre el rendimiento cognitivo sin comprometer significativamente el rendimiento físico a corto plazo.

Introduction

Exercise has long been associated with cognitive performance with several studies finding that fitter people perform better in cognitive tasks. This highlights the association between exercise and long-term cognitive impact. Findings relating to the physiological changes that occur in response to exercise-induced fatigue and its effects on cognitive function and physical performance are contradictory.[1] Moderate intensity continuous aerobic exercise also produces better improved immediate speed processing, selective attention, aspects of inhibitory control, short term memory and selective attention.[2–5]

Intensity seems to have an inverted-U relationship with cognition function. Moderate aerobic exercise increases cognitive but the evidence indicates that anaerobic activity close to or at 100% VO2 max decreases cognitive ability, however the extent to which decreases occur varies n different studies.[2,6]

However exercise physiologists have been suggesting high-intensity interval training (HIIT) as an alternative for both health and sports benefits. HIIT has greater effects on cardiovascular health, metabolic health and aerobic fitness than continuous moderate intensity training. Training sessions are also less time consuming. Within a sports context many team sports are intermittent in nature incorporating high intensity actions and movements combined with low intensity periods. HIIT is more likely to induce higher short-term fatigue levels and if this is more detrimental to cognitive function will impact sports performance.[6] Within a sports context cognitive performance must be accompanied by the physical action as players are expected to be attentive, perceive stimuli, process the information and then act as quick and as accurately as possible. This must continue for the full duration of any competition.[7,8] It is also likely that intense exercise does not have the same effect on all cognitive skills (Figs. 1–5).

The aim of this study was to determine the effects of fatigue following HIIT on physical, reaction time and cognitive performance in university students. It was hypothesised that physical, reaction time and cognitive performances would decrease due to the HIIT induced fatigue.

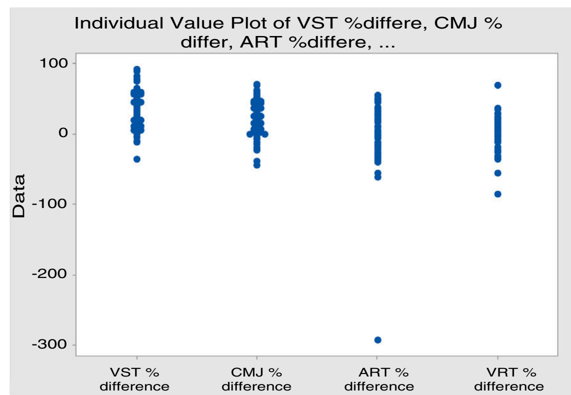

Figure 1 Individual value plot of VST.

Material and methods

The study was based on a quasi-experimental one group pre-post test design. All research methods were in accordance with the Declaration of Helsinki. A total of 44 (male; n = 25; female = 19) recreationally active university students, recruited through convenience, began by performing three pre-tests, namely a cognitive (Victoria Stroop test), physical (countermovement jump test) and simple auditory and visual reaction time test. The aforementioned tests were conducted in random order. To avoid any learning effect, participants first performed a learning trial prior to the test. A maximum of three participants were tested at the same time. Biographical questionnaires including activity level and sport played was also recorded.

Once all three pre-tests had been completed, the participants commenced with a standardised HIIT session in order to induce fatigue. This exercise-induced fatigue was measured by the attainment of a subjective rating greater than 18 on the Borg Rating of Perceived Exertion (RPE) 6–20 Scale (Borg, 1982). Immediately following the HIIT session, participants performed the same three tests.

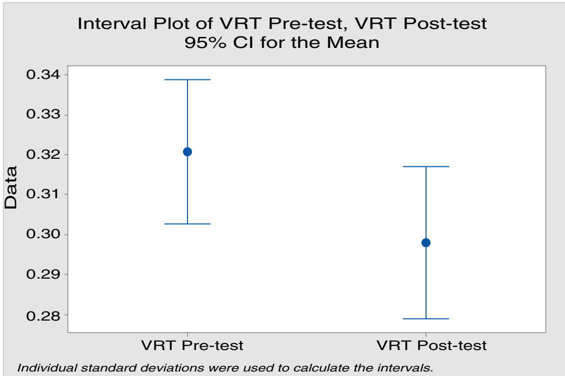

Figure 2 Interval plot of VRT pre-test, VRT post-test.

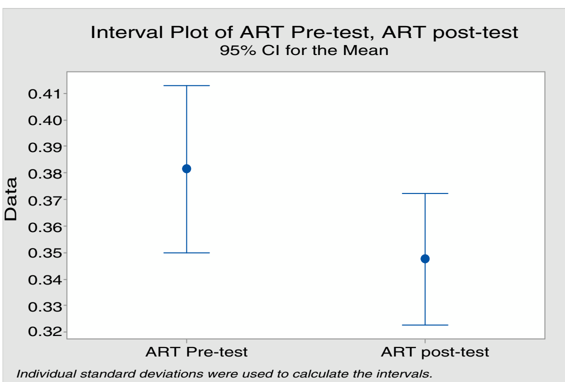

Figure 3 Interval plot of ART pre-test, Art post-test.

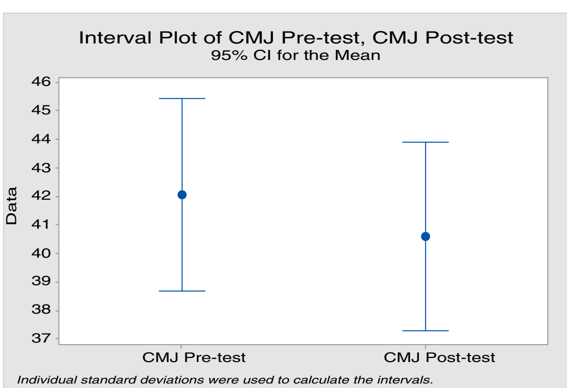

Figure 4 Interval plot of CMJ pre-test, CMJ post-test.

Statistical analysis

To obtain the objectives stated within this study, the quantitative analysis was performed using Microsoft Excel® and Minitab®18 for the purpose of descriptive and inferential statistical analyses. When comparing the pre- and post-tests, the use of t-tests were implemented. Statistical significance was set at $p \leq 0.05$.

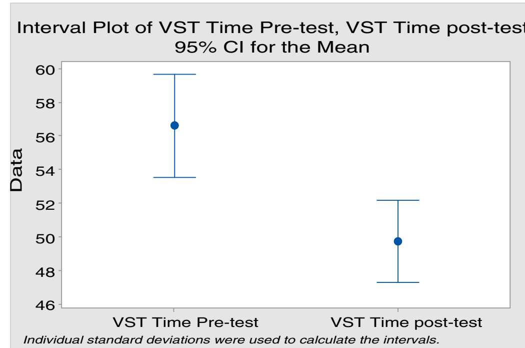

Figure 5 Interval plot of VST time pre-test, VST time post-test.

Results

Significant improvements were found in the Victoria stroop test results with both the number of errors and reaction times improving. Improvements in auditory and visual response time were not significant. Countermovement jump (CMJ) performances decreased, but these changes were not significant (Table 1).

As mentioned above, significant improvements were seen in cognitive processing time, yet when the number of errors acquired during the cognitive processing before and immediately following HIIT were compared, an improvement was seen. This observation does not concur with the speed-accuracy trade off since speed improved without the expected change in accuracy.

Discussion

This study was divided into three components. The cognitive test where number of errors and time it took for the test were recorded, the CMJ which looked at changes in physical performance and the reaction time test which incorporated both the perceptual-cognitive and a physical action. The only significant improvements was in the cognitive test.

The results of the Stroop test were similar to the findings of Alves et al. (2014) who also found improvements in the Stroop test following HIIT. The unexpected result was that even though speed improved in the post test, it did not compromise accuracy of the results. In fact in this study accuracy also improved significantly.

Contrasting results found gradual improvements in the reaction time (as assessed by an audio-visual five-choice reaction task) when young athletes exercised up to approximately 75% of their VO2 peak. Thereafter, the reaction time impaired rapidly, suggesting that intensity seems to play a role in the effects of an acute exercise session on some aspects of cognitive performance.[9]

The findings of this study were similar to one that found no changes in reaction time in soccer players who under 8 min of HIIT.[11] The sample size in this study was small with only 8 participants which could have impacted the results.

It has been demonstrated that physically active persons have quicker reaction times than sedentary persons. Moreover, well-trained athletes were reported to be more capable to maintain their psychomotor skill during fatiguing

Table 1 Descriptive statistics.

Variable		Mean ± Standard deviation	p-Value	Percent difference (%)
VST (sec)	Pre-test	56.52 ± 11.72	0.001**	11.71%
	Post-test	49.20 ± 8.89		
VST accuracy	Pre-test	1.91 ± 2.07	0.04*	
(No. of errors)	Post-test	1.22 ± 1.13		
CMJ (cm)	Pre-test	44.5 ± 12.11	0.17	2%
	Post-test	43.52 ± 12.15		
Auditory reaction (sec)	Pre-test	0.38 ± 0.11	0.16	2%
	Post-test	0.35 ± 0.08		
Visual reaction (sec)	Pre-test	0.32 ± 0.07	0.1	3%
	Post-test	0.30 ± 0.07		

*p < 0.05.
**p < 0.01.

exercise than their less-trained counterparts.[9] With this being said, fitness levels of the participants were not considered in terms of the scope of this study and consequently could have been a possible limitation of the study. All participants were recreationally active.

The results in the reaction time test differed slightly from the findings of Kamijo et al.[15] They compared 20 min sessions at different exercise intensities and looked at the impact on cognitive performance. Following the heavy intensity session they found significantly quicker reaction times when compared to baseline tests and no significant difference in number of errors. The reaction time test used in that study was the flanker task. The current study found slight improvements in the reaction time using both visual and auditory stimuli but the difference was not significant.

A simple reaction time test was used for this study, however people often perform motor tasks in combination with cognitive tasks. For this study it may have been more suited to use a choice reaction time dual test illustrating the effects of interference when performing a fatiguing motor task (particularly at higher intensities) in combination with a cognitive task.

Contrary to what the researchers of this particular study hypothesised, countermovement jump performances did decrease following an acute bout of HIIT, but these changes were not significant ($p > 0.05$). Although there is not much literature pertaining to the effects of HIIT on physical performance, specifically countermovement jump performance, Watkins et al.[12] did find that vertical jump height decreased post-workout following resistance training at approximately 80% of one-repetition maximum. Vertical jump is widely used as a measure of lower body power, and has been used in post-match studies to demonstrate fatigue levels. Considering that the HIIT session used in this study mainly compromised of lower body exercises, muscular fatigue could have affected the ability to voluntarily activate muscle fibres, resulting in a decrease in maximum voluntary strength, power and work capacity.[12]

Performance decrements occurred during a jumping test is likely as a result of neuromuscular fatigue.[14] This may be as a result of the relevant energy systems employed in the VJ test. Energy for extremely short high-intensity exercise (less than 10 s) is supplied by anaerobic metabolism, resulting in the depletion of adenosine triphosphate phosphocreatine (ATP-PC) stores in the muscles which coincides with an increase in inorganic phosphate, hydrogen (H+) ion accumulation, lactate formation, and a decrease in pH. The aforementioned physiological mechanisms have been related to the development of fatigue and a decline in power output.[13]

The exact mechanism explaining the links between cognition and exercise is not yet fully understood. Elevated cerebral blood flow combined with increased levels of BDNF and catecholamines are could to contribute to increased cognitive function following exercise.[2] However, one study found no relationship between cerebral blood flow and cognitive performance following exercise Aerobic exercise increases arousal level and activates specific cortical areas. Increased cerebral blood flow was found to be independent of improved performance in the strop test but factors such as cerebral neural activation and metabolism, increased psychological responses, increased neural activity in the brain, increased left-dorsolateral prefrontal cortex activity could all contribute to the acute effects on cognition following exercise. HIIT causes higher increases in psychological response than moderate activities however Tsukamoto[14] found no difference in cognitive repose following moderate and HIIT sessions. This study compared cognitive performance at different intervals post exercise and found improvements in both the moderate and HIIT groups. The effects however, were longer lasting in the HIIT group which could be related to sustained higher than baseline arousal levels in the HIIT group beyond 20 min when the moderate group had returned to pre-exercise levels.

All the evidence indicates that activity does have a positive effect on acute cognitive performance. There is no consensus on how different durations, intensity and type of exercise affects cognitive performance, and more research must be done to identify how long cognitive improvements last. Reasons for contrasting results from different exercise intensities could be due to variation in fatigue levels and the mechanism of fatigue. Fatigue and its exact courses and effects is still not clearly understood with different theories existing. It is likely that fatigue is due to a combination of physical and central mechanism. Changes in central commands may result. Acute impairment in performance including both an increase in the perceived effort (central fatigue) necessary to exert a desired force and the eventual inability to produce force at the muscular level (local fatigue) are responsible for fatigue.[16]

This study had some limitations. All participants were active, but exact fitness levels of the participants were not evaluated and did not form part of the analysis. This may have consequently altered the results of this study. RPE was used to measure fatigue levels in participants which ensured that each persons workload was based on their subjective assessment of intensity. Potential bias may have been present using RPE as the relativity of the sensation of fatigue may be part of an individual's ability to cope with discomfort. Even though participants first performed a trial run followed by testing for the CMJ as well as the auditory and visual reaction time tests, learning effect could have contributed to the results.

Conclusions

This study found that HIIT improved cognitive function but had no significant impact on reaction time (Auditory or visual) and on physical performance. The findings of this study could be useful to fitness trainers and coaches who prescribe training programs. The results might also be used to ensure that players in various sports can be trained to limit cognitive fatigue and decreases in cognitive function during periods of matches where they are faced with high intensities.

Conflict of interests

Authors declare that they don't have any conflict of interests.

Uncited references

[10,15].

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