

UNIVERSITI TEKNOLOGI MARA

**ELUCIDATING THE INFLUENCE OF
FRUIT-DERIVED POLYPHENOL ON
EXERCISE PERFORMANCE AND
CARDIOMETABOLIC**

FATIN NUR SHAHIRA BINTI ZAMRI

Thesis submitted in fulfilment
of the requirements for the degree of
Doctor of Philosophy
(Sports Science and Recreation)

Faculty of Sports Science and Recreation

February 2026

ABSTRACT

Fruit-derived polyphenols (FDP) possess antioxidant and anti-inflammatory properties, improving exercise performance via nitric oxide-mediated mechanisms. Excess reactive oxygen species contribute to exercise-induced fatigue through inflammation and oxidative damage within muscles. A meta-analysis of randomised controlled trials systematically evaluated the ergogenic effects of FDP supplementation on exercise performance compared to placebo (PLA). This resulted in the identification of 29 publications describing 55 different trials that fit our inclusion criteria with 651 subjects included. The result showed that FDP interventions led to statistically significant improvements in exercise performance compared to PLA. Results of the pooled standardized mean difference (SMD) estimates of all included studies indicate that exercise performance was significantly improved with FDP supplementation compared to PLA (overall SMD = 0.29, 95% CI [0.21, 0.38], $p < .001$). To further the findings of this study, Study 2 examined the influence of fitness status (trained vs. non-trained individuals) on high-intensity intermittent performance using the YYIRTL1. In a randomized, double blind, placebo-controlled crossover design trial, 44 healthy men ingested with cocoa flavanols (CFL) and PLA for 7 days with a 14-day washout period. Compared to PLA, the results showed that FDP supplementation was more effective in trained individuals ($p < 0.05$). To build on these findings, Study 3 investigated whether these improvements were due to acute and chronic supplementation. 15 healthy individuals completed 4-km time trials (TT), with resulted in acute and chronic ingestion of CFL, with substitution of PLA on Day 28 or Day 30, significantly improving exercise performance and cardiovascular benefits ($p < 0.005$). Given that different FDP sources have distinct antioxidant and anti-inflammatory properties, Study 4 was conducted to explore whether single or mixed FDP supplementation strategies are more effective in promoting recovery following high-intensity intermittent exercise. In a randomized, double-blind, placebo-controlled design, 52 collegiate-level males completed a ramp incremental test to exhaustion (TTE). The results indicate that CFL+BRS significantly improved TTE, reduced of blood pressure, lower lactate accumulation at exhaustion, regulated blood glucose and heart rate and influenced the fatigue perception index (RPE) with a p-values less than significance threshold. FDP supplementation, particularly CFL, enhances athletic performance, cardiovascular efficiency, and exercise perception in both trained and untrained individuals. Acute and chronic CFL ingestion leads to greater improvements in exercise performance and cardiometabolic markers. Additionally, mixed FDP sources provide significant benefits in cardiovascular function, metabolic regulation, and fatigue reduction.

ACKNOWLEDGEMENT

First and foremost, I would like to thank my creator, the Most Merciful and the Most Gracious Allah S.W.T for providing me with this valuable and beneficial opportunity to demonstrate my capabilities and making it all possible for me to complete this thesis. His guidance has shown me that there is a light at the end of every tunnel and for teaching me the importance of Sabr, in every situation even during times when I felt most doubtful. I would also like to send peace and blessings upon the Messenger Prophet Muhammad (peace be upon him), who has guided me and blessed me to a better life.

I would also like to thank Dr. Nurul Diyana binti Sanuddin, my main supervisor for her patience, assistance and encouragement throughout the completion of this dissertation. Besides, having someone who is capable in many aspects, high in knowledge and very humble, is such an honour to have an outstanding co-supervisor, Mr. Adam Linoby bin Ronny Linoby. A special thanks goes to my father, Zamri bin Ramsi, my mother, , my siblings, and the entire family for their unwavering support and encouragement throughout this journey. Their belief in me has been a constant source of motivation. This thesis is also dedicated to the ones I have loved and lost. Though they are no longer with us, their love, guidance, and memories continue to inspire me every day. Their presence will forever remain a part of this journey.

To the one whose unwavering faith in me fuelled my promise to reach for the stars, this achievement is a quiet tribute to the love and strength that guided me every step of the way. Though time and distance separate us, this success will always carry the mark of your inspiration.

I would like to express my heartfelt gratitude to my best friend, Nurin 'Aqilah binti Nazrul Azri, for her unwavering support, encouragement, and invaluable assistance throughout my thesis. Her continuous motivation, insightful feedback, and belief in me helped me overcome many challenges. Her presence during my toughest moments provided immense strength, making this journey truly fulfilling. I am also grateful to my friends for their support and encouragement during tough times. Their friendship has made this journey more fulfilling. Thank you to everyone who helped and supported me along the way, your encouragement has been crucial to my success.

I extend my deepest gratitude to the Faculty of Sport Science, Negeri Sembilan Branch, Seremban 3 Campus and Pahang Branch, Jengka Campus for their invaluable support and resources throughout my thesis. I also extend my sincere thanks to all the research participants for their time, cooperation and valuable contributions to this study.

“Last but not least, I wanna thank me, I wanna thank me for believing in me, I wanna thank me for doing all this hard work, I wanna thank me for having no days off, I wanna to thank me for never quitting, I wanna to thank me for always being a giver and tryna give more than I receive, I wanna thank me for tryna do more right than wrong, I wanna thank me for just being me at all times.”

TABLE OF CONTENTS

	Page
CONFIRMATION BY PANEL OF EXAMINERS	ii
AUTHOR'S DECLARATION	iii
ABSTRACT	iv
ACKNOWLEDGEMENT	v
TABLE OF CONTENTS	vi
LIST OF TABLES	xiii
LIST OF FIGURES	xvi
LIST OF SYMBOLS	xx
LIST OF ABBREVIATIONS	xxi
LIST OF NOMENCLATURES	xxii
CHAPTER 1: INTRODUCTION	1
1.1 Research Background	1
1.2 Problem Statement	5
1.3 Purpose of the Study	13
1.4 Research Questions	16
1.5 Research Objectives	16
1.6 Research Hypotheses	17
1.7 Scope of Study	18
1.8 Operational Definitions	19
1.9 Delimitations	21
1.10 Limitations	22
1.11 Assumptions	23
1.12 Significance of the Study	24
1.13 Overview of Thesis Structure and Associated Publications	25
CHAPTER 2: LITERATURE REVIEW	29
2.1 Exercise Performance and Aetiology of Fatigue	29

CHAPTER 1

INTRODUCTION

1.1 Research Background

Generally, physical exercise influences the biochemical equilibrium of muscle cells, such as the inorganic phosphate (Pi) in adenosine triphosphate (ATP), protons, lactate in anaerobic capacity, and free magnesium ions (Mg^{2+}) within the cells. These biochemical products directly affect the mechanical machinery of the muscle cells, such as mitochondria. In addition, they have a negative impact on various muscle cell organelles involved in the transmission of neuronal signals (Müller et al., 2019). The muscle metabolites and the heat generated by muscle contraction are released into the internal environment, disrupting its equilibrium (Osilla et al., 2022). Compared to resting conditions, the tremendous increase in muscle metabolism induces greater muscle blood supply, which increases the blood circulation system and gas exchange. The exercising muscle must be supplied with nutrients, depleting energy reserves elsewhere in the body (Brooks, 2022). In addition, the contraction of muscle fibres causes the release of cytokines, which have numerous effects on other organs, including the brain. As a result, the sensation of fatigue is instigated by various mechanisms ranging from the accumulation of metabolites within muscle fibres to the generation of an inadequate motor command in the motor cortex (Marino, 2019).

In recent years, the use of naturally occurring plant extracts and bioactive plant compounds to boost physical performance, exercise recovery, and health have increased at both the recreational and elite sports levels, with plant extract supplementation being the most popular options. As athletes push the limits of what is physically possible, the difference between victory and defeat comes down to a matter of millimetres and milliseconds, and sporting supplements are becoming increasingly popular. Polyphenols have emerged as a new area of nutrition research. A growing body of research suggests that polyphenol consumption may play an important role in health by regulating metabolism, weight, chronic disease, and cell proliferation (Giller et al., 2021). Investigating ergogenic effects of polyphenol in male animals, humans (Fraga et al., 2019) and epidemiological (Durazzo et al., 2019) studies demonstrate antioxidant and anti-inflammatory properties that could have preventive and therapeutic effects for