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AN OVERVIEW OF THE PHYSICAL AND NON-PHYSICAL HEALTH EFFECTS OF MARATHON RUNNING

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ABSTRACT

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The purpose of this study is to summarize the current scientific literature and knowledge on the physical and non-physical health effects of marathon running. Five databases were queried, using the keywords *marathon*, *endurance, training, wellness, injury*, *distance*, *runner*, *running*, *health*, *benefit*, *respiratory*, *infection*, *immunity*, and/or *risk* in various combinations. Articles eligible for inclusion analyzed the effects of long-distance running (13.1 miles or greater), and were published in peer-reviewed English language journals after 1976. Of the 71 articles which meet the inclusion criteria, several discussed more than one aspect of marathon running; 26 discussed physical benefits, 11 discussed non-physical benefits, 40 discussed physical risks, and 4 discussed non-physical risks. The physical health benefits of exercise are well known, however, many questions remain about the health risks and implications across the spectrum of wellness. These questions must be answered before the effects, benefits, and risks of long-distance running can be understood, and scientifically validated recommendations published.

Keywords: marathon running, distance running, training, runner, exercise

CHAPTER ONE: INTRODUCTION

According to Mathews et al., 2012, the mythical herald Pheidippides witnessed the Greek victory over Persia at the Battle of Marathon. Despite his battle-weariness, he marshalled the internal strength to run non-stop from the battlefield to Athens, a remarkable 40 kilometers. The authors further explain that, according to legend, Pheidippides burst into the Athenian senate, declaring "*Niki*!" (Victory!) only to collapse and die moments later, exhausted from his battle wounds and the strain of his run. During the reestablishment of the modern Olympic Games in Greece, Michel Breal became enthralled with the legendary Pheidippides and his run, and decided to create a long-distance race to commemorate the ancient Greek warrior (MarathonGuide.com, 2009). Named after the location of the mythical battle, the marathon was established as the final event in the Olympic Games. The Olympic race influenced competitors from the US competing in Athens in 1896, who then established their own marathon in 1897 called the Boston Marathon (MarathonGuide.com, 2009). The Boston Marathon is still considered one of the most prestigious of all marathons.

A marathon any footrace whose distance is 26.2 miles (Jassal et al., 2009). Once widely perceived as a sport exclusive to elite athletes, according to Bertram, Prebeau-Menezes, and Szarko (2013) "marathon racing has gained broad appeal as a fitness achievement for many nonelite runners" (p. 6). Participation in marathons has been dramatically increasing in popularity in the US since the late 1970's. In 1976, only 25,000 people finished a marathon in the US (Burfoot, 2007). In 2001, this number increased to more than 366,000 (USA Track and Field, 2004), and in 2014, the number of marathon finishers reached an all-time high of 550,637 (*Running USA*, 2014). Although the proportion of female marathon finishers has increased since 1980, the majority of marathon finishers are male. For example, in 2013, 43% of marathon participants were female and 57% were male (*Running USA*, 2014). In contrast to the trends in gender participation, the percentages of marathon finishers by age group has remained relatively constant since 1995. In 2012, 47% of finishers were over 40 years of age, 50% were between the ages of 20 and 39, and 3% were under 20 years of age (*Running USA*, 2014). The gender and age-group participation rate for marathon finishers by year for the years 1980, 1995, 2000, 2005, 2010, 2011, 2012 and 2013 is represented in Table 1.

Table 1

Marathon Gender and Age Group Finishers by Year

	1980	1995	2000	2005	2010	2011	2012	2013
Women	10%	26%	38%	41%	41%	41%	42%	43%
Men	90%	74%	62%	59%	59%	59%	58%	57%
Masters (40+ years)	26%	41%	44%	44%	46%	46%	46%	47%
Open (20-39 years)	69%	57%	54%	54%	52%	52%	52%	50%
Juniors (Under 20)	5%	2%	2%	2%	2%	2%	2%	3%

Note: Data from *Running USA* (2014)

Half-marathons, a distance of 13.1 miles (Jassal et al., 2009), have become increasingly popular in the US as well (Mohseni et al., 2011). In 1990, only 303,000 people finished a half-marathon in the US. In 2004, the number of finishers increased to 612,000 and in 2014, the number of finishers reached an all-time high of 2,046,600 (*Running USA*, 2014). According to the data reported by *Running USA* (2014), the majority of full-marathon finishers are historically male, however, since half-marathon data collection began in 2006 the majority of half-marathon finishers in the US have been female. In 2013, 61% of half-marathon finishers were female; this was the highest proportion reported for any race distance that year (*Running USA*, 2014). The *Running USA* (2014) data further indicates that although the gender participation trends are different for half-marathons, the age-group distribution of participants parallels marathons. In 2013, 41% of half-marathon finishers were over 40 years of age, 55% were between the ages of 20 and 39, and 3% were under the age of 20. Half-marathon participation according to gender and age group for the years 2006-2013 is represented in Table 2.

Table 2

Half-marathon Gender and Age Group Finishers by Year

	2006	2007	2008	2009	2010	2011	2012	2013
Women	53%	55%	56%	57%	59%	59%	60%	61%
Men	47%	45%	44%	43%	41%	41%	40%	39%
Masters (40+ years)	41%			39%	36%	40%	41%	41%
Open (20-39 yrs)	56%			58%	61%	56%	55%	55%
Juniors (Under 20)	3%			3%	3%	4%	4%	4%

Note: Data from *Running USA* (2014)

To promote and maintain health, the American College of Sports Medicine (ACSM) recommends that adults participate in a minimum of 30 minutes of moderate-intensity physical activity 5 days a week or 20 minutes of vigorous-intensity physical activity three days a week (Haskell et al., 2007). The Haskell et al. (2007) authored ACSM report suggests that individuals who wish to further improve their fitness levels exceed these recommended health-maintenance amounts. Typical marathon training plans include running distances ranging from 30 miles a week for novices to 100 miles or more for elite runners. According to MarathonGuide.com (2009), the mean pace for completing a marathon in 2009 was 4:35:42, which is approximately 10 minutes/mile. However, the author further notes that an elite runner pace is approximately 5 minutes/mile. By using marathon pace multiplied by weekly training distance, it can be inferred that most marathon runners are spending 3 or more hours/week running in order to prepare for upcoming events. Thus, the typical amount of vigorous exercise that marathon and long-distance runners undertake is at least 3 times the minimum ACSM (2007) recommendations.

Because of their training regimen, these runners represent a unique subgroup of the American population that meets, and may greatly exceed, the national activity guidelines. As such, examining the health and wellness of marathon runners provides insight into the positive and negative effects of regular vigorous-intensity physical activity.

CHAPTER TWO: BACKGROUND

Health Benefits

Training for and running in a marathon requires many hours of habitual, dedicated cardiovascular exercise. Consequently, this type of exercise regimen offers benefit in many areas, including physical, emotional, or social wellbeing. Physiological advantages include increased HDL cholesterol, bone density, and VO_2 max retention, and decreased BMI, blood pressure, and resting heart rate (Drysdale, Collins, Walters, Bird, & Hinkley, 2007; Khosla & Campbell, 1982; Williams, 1996, 2009a).

Health Risks

Marathon running presents potential health-related risks and increased morbidity, mortality, and injury related to participation. Over-training injuries as well as increased likelihood of acute renal failure, hyponatremia, and sudden cardiac death may occur while running (Clarkson, 2007; Fredericson & Misra, 2007; T. D. Noakes, 1987). In 2006 (a year with 440,000 marathon finishers) 7 runners suffered fatal cardiac arrest, and in the 2009 Detroit half-marathon, 3 runners died (Williams, 1996). Although these deaths have raised questions about the severity of risks of marathon running, it is important to remember that the relative risk of severe adverse events during marathon participation is infinitesimal. As Paul T. Williams (2009), developer of the National Runner's Health Study, said "whether the health benefits of marathoning (*sic)* outweigh its risk will depend in part on whether there are additional benefits to marathon training and participation" (p. 1).

CHAPTER THREE: SIGNIFICANCE

According to the World Health Organization (2006), “[h]ealth is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity” (p. 2). It is clear from this definition that a health behavior cannot be evaluated solely according to the physical dimensions of health. It must instead be assessed in light of the continuum of wellness; social, spiritual, emotional, intellectual, occupational, environmental, and physical (Miller & Foster, 2010). Unfortunately, the current literature on long-distance running focuses almost exclusively on the physical effects with very little research examining any other dimension of health for either elite or recreational runners (Robbins, Powers, & Burgess, 2010). Since recreational runners lack the same physical and mental training of elite marathon runners (Buman, Omli, Giacobbi Jr, & Brewer, 2008), it is likely that recreational runners experience different physical and non-physical effects. Despite this, there is a dearth of literature examining the effects of recreational long-distance running. This review will address these deficiencies by identifying and summarizing the existing literature on long-distance running, as well as making recommendations for future research.

CHAPTER FOUR: OBJECTIVE

The purpose of this review is to systematically examine and organize the scientific literature addressing the physical and non-physical health risks and benefits of recreational marathon running.

CHAPTER FIVE: METHOD

Data Sources

Five electronic databases spanning the academic fields of health, medicine, psychology and sociology were searched. These databases were Academic Search Premier, ERIC, Health Sciences, MEDLINE, PsycINFO, and Sociological Abstracts. Each database was searched using the following key terms in various combinations: *marathon*, *endurance*, *training*, *wellness*, *injury*, *distance*, *runner*, *running*, *health*, *benefit*, r*espiratory*, *infection*, *immunity*, and/or *risk*. Furthermore, the reference lists of all identified articles were reviewed to locate additional articles that key-term searches failed to discover.

Inclusion Criteria

In order to be included in this review, studies were published in a peer-reviewed English-language journal after 1976. They focused on long-distance running (distances of 13.1 miles or longer) and either used empirical data to examine the relationship between distance running and health-related risk or benefit, or provide statistical data unavailable elsewhere in the literature (e.g., many of the current trends in long-distance running are published via websites or lay journals). For these reasons, literature reviews summarizing current trends or report participation or other statistical trends were included. These inclusion criteria are presented in Table 3.

Table 3

Inclusion Criteria

Criteria	Description
Publication date after 1976	Major modification of New York marathon course and New York Academy of Sciences Meeting
Published in peer review journal	This review is limited to empirical evidence; thus, only peer reviewed articles were sought
Published in the English language	The premier published health and running journals are in English, additionally due to translational and other issues only English-language articles were included
Focus on long-distance running	Only articles that examined running distances of 13.1 miles or greater at one time were selected
Empirical study	Articles that used a scientific approach to examine how marathon running impacts health or provided statistical data were selected

The review discussed herein spans research investigating risks and benefits of marathon running from the years 1976 – 2015. The year 1976 was selected as the base point for inclusion in this study for two reasons. First, the 1976 New York City Marathon marked a watershed in marathon running; that year the course changed from several loops around Central Park to a circuit of the metropolis that touched all 5 boroughs (Noakes & Martin, 2002). This was the first time a major city added the element of large-scale physical fitness participation to what was previously a purely athletic event (Burfoot, 2007). Because of these changes, thousands of fitness enthusiasts joined elite athletes in the challenge of completing a marathon, establishing marathon running as an achievable fitness pursuit. Second, the increased participation prompted the New York Academy of Sciences, organized by Paul Milvy, to meet and discuss marathon running research and future direction (Roberts, 2007a). This meeting represented the most comprehensive scientific examination of marathon running to date. Peer-reviewed articles were the basis of the research conducted on marathon running, and a marathon was established as any event with a distance of 13.1 miles or longer. Only articles that utilized a scientific approach to examine marathon running were selected for this review. Because most premier health and running journals are published in English, this review excluded any non-English language articles.

Exclusion Criteria

Studies focusing on athletic/physiological performance measures (i.e., VO_2 max, lactate threshold, fluid replacement, and the impact of nutritional factors on performance) were excluded from this review, because they do not have a direct effect on the health and/or wellness of marathon runners. While it is quite clear that such studies examine aspects of physical health, the decision to exclude them is based upon their emphasis on examining procedures for *improving marathon runner performance* (e.g., running speed, endurance) rather than focusing on overall health effects. For the same reason, articles focusing on biomechanics, running economy, temperature conditions and genotypes were excluded.

Articles based on the National Runners' Health Study, a two-page questionnaire distributed nationally at races and annually from 1991-2000 to subscribers of *Runner's World*, the nation's largest running magazine, failed to meet the inclusion criteria for this study. The respondents to this survey consisted of runners who completed a variety of race distances, including 5K and 10K competitions (Roberts, 2007a). Although the majority of responses were from long-distance runners, their responses were not separated from the responses of participants who ran shorter distances; thus, the reason for excluding articles from the National Runner's Health Study.

Data Extraction and Synthesis

The Matrix Method was employed to identify, organize, and analyze pertinent literature (Garrard, 2013). This method was selected due to the comprehensive process of assessment and data analyses it offers. The structure of the Matrix Method mirrors a Literature Review book, which includes a comprehensive record of all documentation utilized in structuring the review of the literature. The Matrix Method consists of four sections of procedural documentation: (a) a paper trail, which is the complete record of the meticulous search process; (b) a documents section indicating all scholarly research involved in the review; (c) a review matrix abstracting each document included; and (d) a synthesis section, wherein the outcome of the utilization of the review matrix is documented (Garrard, 2013). These sections are depicted in Figure 1.

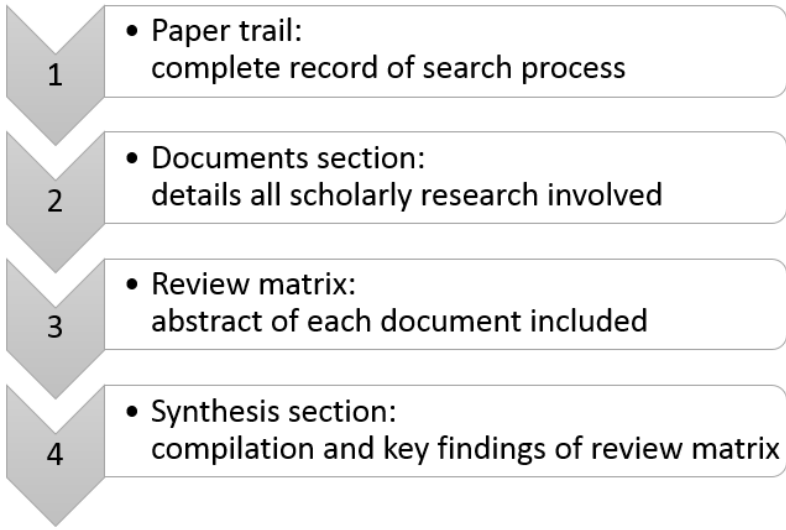

Figure 1. The four sections of the Matrix method procedural documentation.

CHAPTER SIX: RESULTS

The search of the selected databases yielded 108 articles based on the relevant keywords. Of these, 11 were duplicates, and 36 did not meet the inclusion criteria. An additional 10 articles were located from the reference sections of selected articles. This resulted in a final article count of 71. The study selection process is depicted in Figure 2.

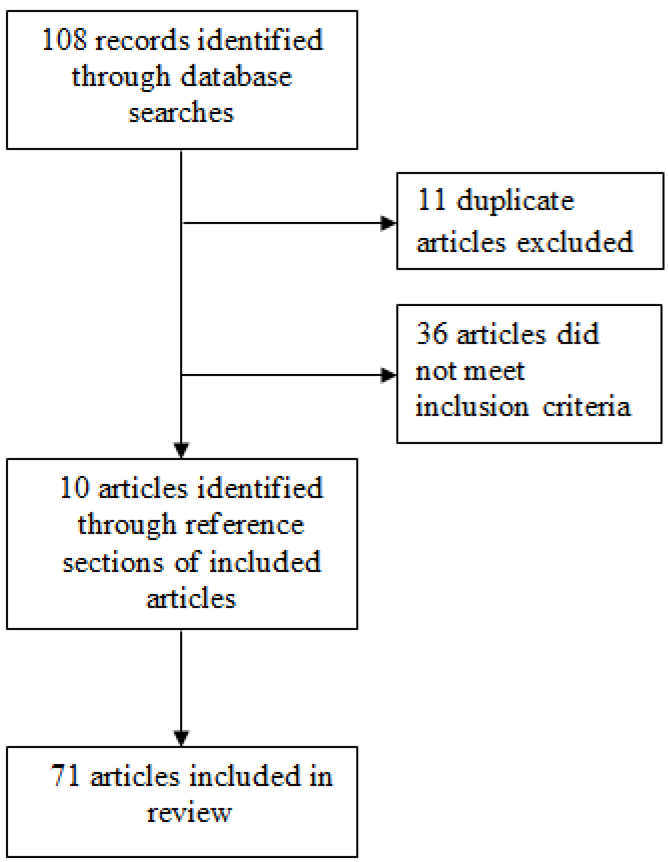

Figure 2. Flow chart of the study selection process.

The results are analyzed according to the categories of physical health benefits, non-physical health benefits, physical health risks, and non-physical health risks. Because several of the 71 articles discussed more than one aspect of long-distance running, many overlapped in scope; 26 discussed physical benefits, 11 non-physical benefits, 40 physical risks, and 4 non-physical risks. Due to the overlap, the articles add to 81. The lead author, publication year, purpose of the study, sample size, study design, and study conclusion(s) for each article reviewed is depicted in Tables 4, 5, 6, and 7.

Health Benefits

Physical

The association between long-distance running and beneficial health outcomes has contributed to the surge of marathons across the US (Nudel et al., 1989). The most prevalent physical health benefits of marathon running relate to cardiovascular health. As long-distance runners participate in training and marathon events, they exceed the recommended daily recommended amount of exercise. The extreme requirement of physical endurance leads to physiological changes proven to impact bone density, heart function, and cholesterol levels. Substantial increases in HDL cholesterol levels in men, women, vegetarians, and omnivores were established (Roberts, 2007b). The increase in HDL levels among male and female marathon runners was reported by Williams et al. (1996). Runners were found to have lower resting pulse rates, which may be an indicator of improved health and mortality (Khosla & Campbell, 1982). The cardiovascular risk factors of runners are related to their degree of fitness as measured by finishing time (Ketelhut, Ketelhut, Messerli, & Badtke, 1996). Current research supports the concept that continued running late into life mitigates the decline in physiological function across a runner's lifespan and is beneficial for overall health (Trappe, 2007). Similarly, current literature supports the belief that aging as a biological process can be sped up or slowed down by multiple lifestyle factors, including marathon running (Leyk et al., 2009). In fact, vigorous or moderate activity that exceeds or meets 450 minutes a week is linked to a longer life expectancy (Ruiz, Fiuza-Luces, Garatachea, & Lucia, 2014).

Marathon running was found to impact more than cardiovascular health. For instance, weight-bearing exercises, such as routine running, were shown to decrease the decline in bone-density with age (Drysdale et al., 2007). Young marathon runners who began exercising at the ages of 4-12 years old were found to enjoy high physical fitness levels and suffered no growth-stunting as a result of their training (Nudel et al., 1989).

The risk of stroke has been found to be substantially reduced in marathon runners (Williams, 2009b). Endurance training is associated with significantly lower medication use for hypertension, hypercholesterolemia, and diabetes (Williams, 2009b). There also is preliminary evidence that the vigorous physical activity associated with running may reduce the risk of glaucoma (Williams, 2009c). Williams (2007) found that as marathon runners of both sex aged, they gained less weight in proportion to their levels of sustained vigorous activity; this long-term effect is in addition to the acute weight loss that occurs with increased activity. Additionally, he noted that vigorous exercise significantly reduces the incidence of diabetes, due in part to the reduction of age-related weight gain (Williams, 2007). The lead author, publication year, purpose of the study, sample size, study design, and study conclusion(s) for each of these articles discussing physical health benefits is represented in Table 4.

Table 4

Review Matrix for the Physical Benefits of Long-distance Running

Lead Author	Pub. Date	Study Purpose	Sample Size	Study Design	Conclusion(s)
Bassler	1977	To examine the deaths from Atherosclerosis in 42-km male runners.		Literature Review	To date there have been no reports of fatal atherosclerosis, historically proven, among 42-km men.
Day & Thompson*	2010	To examine the long-term cardiac risks and benefits associated with marathon running.		Literature Review	Although sudden cardiac deaths associated with marathon running are very rare, precautions should still be taken in order to investigate prodromal symptoms.
Drysdale	2007	To determine calcaneal broadband ultrasound attenuation of marathon race participants and compare this information with previously obtained normative data.	401	Quantitative Quasi-Experimental	The study supports that weight-bearing exercise, such as routine running, may decrease the known decline in bone-mineral-density with age by maintaining bone architecture as reflected by measured broadband ultrasound attenuation.
Estok et al.*	1986	To assess marathon and non-marathon female runners' physical, psychosocial, and menstrual changes.	95	Quantitative Quasi-Experimental	A high incidence of knee injury was apparent in both groups of runners while the marathoners had a higher incidence of heel pain and stress fractures. Psychosocial variables such as anxiety, self-esteem, family/spouse relationships and addictive behaviors did not differ significantly between the two groups.
Fredericson*	2007	To review the literature evaluating the epidemiology and etiology of marathon injuries and provide suggestions for future research.		Literature Review	More experienced runners are less prone to injury, with the number of years running being inversely related to incidence of injuries. A graduated training program helps prevent injuries. Knee injuries are the most common seen in marathon runners.

Table 4
(continued)

Lead Author	Pub. Date	Study Purpose	Sample Size	Study Design	Conclusion(s)
Holloszy*	1977	To study the adaptations to endurance exercise training that make it possible for an individual to run 26.2 miles at an 11 to 12 mph pace.		Literature Review	The adaptive increase in the working muscle cells of trained as compared to untrained individuals. The adaptive increase in the capacity to oxidize fatty acids also results in a greater reliance on fat oxidation for energy during work of the same relative intensity in the trained state; this helps to protect against depletion of glycogen stores.
Karkoulias	2007	To assess the hormonal responses to marathon running in non-elite athletes.	11	Quantitative Quasi-Experiment	The results indicated an increase in serum cortisol and prolactin levels and a decrease in testosterone following the race. All levels returned to baseline after one week.
Ketelhut*	1996	To assess cardiovascular risk factors in marathon runners with different degrees of fitness.	30	Quantitative Quasi-Experimental	At the extreme end of a continuum such as represented by well-conditioned, middle-aged marathon runners, cardiovascular risk factors are related to the degree of fitness, as measured by the marathon running time.
Khosla	1982	To perform a study on the slow resting heart rate of long-distance runners.	103	Quantitative Quasi-Experimental	Resting pulse rate declines in athletes who train, which is advantageous to completing a marathon in a low time. Its importance as an indicator of health and mortality has been neglected in recent epidemiological studies.
Kobayashi et al.	2005	To determine the effect of a marathon race on serum muscle enzymes, serum lipid and lipoprotein concentrations.	15	Quantitative Quasi-Experimental	Studies showed elevated levels of triglyceride, high density lipoprotein cholesterol, serum lactate dehydrogenase, and serum creatine kinase post-race. Then levels all dipped for the following 24 hours to three days only to return to baseline within one week.
Leyk et al.	2009	To examine the relationship between marathon runners and Lifestyle Parameters.	6992	Quantitative Quasi-Experimental	The findings strengthen the concept that considers aging as a biological process that can be considerably speeded up or slowed down by multiple lifestyle related factors.
Luden et al.	2012	To investigate skeletal muscle plasticity in marathoners training for their first marathon.	6	Quantitative Quasi-Experimental	The study indicated that marathon training leads to specific skeletal muscle adaptation in order to perform a long-distance event of 42.2km of running.

Table 4
(*continued*)

Lead Author	Pub. Date	Study Purpose	Sample Size	Study Design	Conclusion(s)
Noakes*	1987	To study the 36 cases of heart attack or sudden death in marathon runners for history of heart disease or sudden death in marathon runners for history of heart disease or coronary risk factors.	36	Quantitative Non-Experimental	Marathon runners, especially those with a family history of heart disease and other coronary risk factors, should not consider themselves immune to either sudden death or coronary heart disease.
Nudel*	1989	To study the physiological and psychological characteristics and the running histories of young marathon runners.	16	Quantitative Non-Experimental	Runners had high physical fitness and no growth retardation.
Ruiz et al	2014	To assess data determining the protective benefits against cardiovascular disease and premature death in former endurance athletes.		Literature Review	Current research indicates that there is evidence that regular intense endurance exercise can have protective benefits against cardiovascular disease and premature death, but there is an optimal dose that must still be determined.
Trappe	2007	To overview the current state of knowledge on running performance, cardiovascular and skeletal muscle changes with age and distance running.	~50	Quantitative Non-experimental	Current research supports the idea that continued running late into life attenuates a decline in physiological function with age and is beneficial for overall health.
Weibel*	2007	To determine the magnitude of ketone production in ultramarathon runners and what affect if any this has on performance.	31	Quantitative Non-experimental	Two runner sub-populations were revealed, runners who produce ketones, and runners who do not. The level of ketones produced did not affect overall distance run. Although ketones did not affect race performance, long-term health consequences are unknown.
Whyte et al.	2005	To assess the impact of marathon running on cardiac structure and function in recreational runners.	52	Quantitative Experimental	The study examined markers of oxidative stress and cardiac-specific damage related to left ventricular function.
Williams*	1996	To examine the dose-response relation in women between risk factors for coronary heart disease, particularly the concentration of HDL cholesterol, and vigorous exercise at levels that exceed official guidelines.	1837	Quantitative	Substantial increases in HDL cholesterol concentrations were found in women who exercised at levels exceeding current guidelines; higher HDL cholesterol concentrations could provide added health benefits to these women.

Table 4
(*continued*)

Lead Author	Pub. Date	Study Purpose	Sample Size	Study Design	Conclusion(s)
Williams	1997	To test whether: running benefits vegetarians, alcohol and running distance contribute independently to concentrations of HDL cholesterol, and running mitigates the hypertensive effects of alcohol.	9242	Quantitative Quasi-Experimental	Running distance in vegetarians has the same relation to HDL and adiposity as reported previously for omnivores; alcohol and running distance contribute independently to higher HDL; running does not abate the hypertensive effects of alcohol in men.
Williams	2006	Although training studies show that exercise produces acute weight loss, it is unclear whether long-term maintenance of vigorous exercise attenuates the trajectory of age-related weight gain.	8340	Quantitative Quasi-Experimental	As they aged, men and women gained less weight in proportion to their levels of sustained vigorous activity. This long-term beneficial effect is in addition to the acute weight loss that occurs with increased activity.
Williams	2007	To examine the relationship between changes in reported vigorous exercise and self-reported physician-diagnosed diabetes in active men.	25988	Quantitative Non-Experimental	Vigorous exercise significantly reduces diabetes incidence, due in part to the prevention of age-related weight gain and in part to other exercise effects.
Williams	2008	To assess the dose-response relationship between vigorous physical activity and the participant-reported physician-diagnosed stroke.	41402	Quantitative Non-Experimental	The risk for incident stroke is substantially reduced in those who exceed the guideline physical activity level, which cannot be attributed to less hypertension, diabetes, hypercholesterolemia, or body weight.
Williams	2009	To assess whether an isolated report of lower diverticular risk in physically active men, particularly those who ran, can be verified among older men and women using the National Runners' Health Study.	10736	Quantitative Quasi-Experimental	The results demonstrate an inverse association between vigorous physical activity and incident diverticular disease among older men and women but are limited by their reliance on self-reported physician diagnosis.
Williams	2009	To assess the dose-response relationship of vigorous physical activity or cardiorespiratory fitness to the risk of incident glaucoma.	29854	Quantitative Quasi-Experimental	Data provides preliminary evidence that vigorous physical activity may reduce glaucoma risk.
Williams	2009	To test whether the prevalence of hypertension, hypercholesterolemia, and diabetes declines with marathon participation independent of annual running mileage.	107324	Quantitative Quasi-Experimental	Findings show that being genetically predisposed to run longer distances or endurance training itself is associated with substantially lower medication use for the three afflictions, even when adjusted for total annual running distance.

Non-physical

Research indicated that apart from the physical benefits of regular exercise, psychological well-being is increased with rigorous physical activity such as marathon training (Hassmén & Blomstrand, 1991). Overall, marathon runners are characterized as having positive mental health attributes, often recognized as a consequence of training and competition (Morgan & Pollock, 1977).

Compared to non-athletes, marathon runners' superior levels of mental health may aid them in coping with (and perhaps benefit from) the stressors inherent to marathon training (Raglin, 2007). For sufferers of depression, running may help to work as a non-pharmaceutical anti-depressant (Leedy, 2000; Morgan & Pollock, 1977). Running also has shown to improve self-esteem while inhibiting the development of anxiety and depression (Estok & Rudy, 1986). High levels of commitment to running were not found to be associated with dependency or addiction-type problems (Leedy, 2000). The most highly committed runners are strongly motivated by health benefits, and have more positive mental health outlooks than do the least committed runners (Morgan & Pollock, 1977).

Endurance training may even function as a protective mechanism for cognitive abilities (Winker et al., 2010). Physical activity itself has proven to increase cell proliferation and neurogenesis in the hippocampus region of the brain, allowing for more synaptic plasticity and long-term storage capacity (Winker et al., 2010). The effects of endurance training also could slow the progression of Alzheimer's disease by increasing circulation in the brain, which may indirectly reduce vascular risk factors (Winker et al., 2010). Implicit memory can be enhanced by completion of a marathon as indicated by the study conducted by Eich and Metcalfe (2009), because strenuous exercise imposes extreme physical demands and may result in neuro-hormonal changes that can alter the functioning of the memory (Eich & Metcalfe, 2009).

The lead author, publication year, purpose of the study, sample size, study design, and study conclusion(s) for each article discussing non-physical health benefits is represented in Table 5.

Table 5

Review Matrix for the Non-physical Benefits of Long-distance Running

Lead Author	Pub. Date	Study Purpose	Sample Size	Study Design	Conclusion(s)
Allegre*	2007	To examine the relative influence of individual factors and environmental context of physical activity on exercise dependence.	95	Quantitative Quasi-Experimental	The strongest predictors of exercise dependence were individual factors (age and BMI). Exercise dependence could provide interesting insight into the promotion of physical activity as a health-related behavior.
Clitsome	1977	To conduct a large scale study (n=100 or more) using the Myers-Briggs Type Indicator study personality type without inclusion of psychopathology.	100	Quantitative Quasi-Experimental	Findings revealed marathoners to be more introverted when compared with the general population, and did not show any statistical difference between individuals within the group regarding variables examined by the MBTI.
Eich & Metcalfe	2009	To examine the effects of marathon running on implicit and explicit memory.	261	Quantitative Quasi-Experimental	When runners were tested following a marathon, impairment was shown in the explicit memory task and enhancement in implicit memory task.
Estok et al.*	1986	To assess marathon and non-marathon female runners' physical, psychosocial, and menstrual changes.	95	Quantitative Quasi-Experimental	A high incidence of knee injury was apparent in both groups of runners, while the marathoners had a higher incidence of heel pain and stress fractures. Psychosocial variables such as anxiety, self-esteem, family/spouse relationships and addictive behaviors did not differ significantly between the two groups.
Filo et al.	2011	To examine the levels of motivation for charity sport event participation.	1257	Quantitative Quasi-Experimental	Regression analysis indicated that recreation based and charity based motives contribute to a level of attachment to a marathon event.
Gontang	1977	To assess whether or not there is a relationship between personality type and sub-3-hour marathon running.	50	Quantitative Non-Experimental	The results of the MBTI revealed that there were twice as many introverts as there were extraverts and twice as many judging types as there were perceiving types.
Goodsell & Harris	2011	To examine family life for those who participate in marathons.	46	Qualitative	The effects of marathon running on families, how families effected marathon running, how conflicts arose and were dealt with and issues with gender differences were discussed.

Table 5
(*continued*)

Lead Author	Pub. Date	Study Purpose	Sample Size	Study Design	Conclusion(s)
Leedy*	2000	To measure the anxiety and depression traits for a heterogeneous group of runners. Included are the runner's motivations for running and their training patterns.	276	Quantitative Non-Experimental	The study provides an indication that high levels of commitment to running need not be associated with dependency or addiction type problems. The most highly committed runners are strongly motivated by health benefits, and have more positive mental traits than do the least committed runners.
Morgan	1977	To examine the extent to which psychological factors can be useful in characterizing the marathoner.	27	Quantitative Quasi-Experimental	It is concluded that elite marathon runners are characterized by positive mental health from an affective standpoint, and this positive affect is regarded as a consequence of training and competition.
Raglin	2007	To highlight findings of psychological research involving marathoners.		Literature Review	Research has demonstrated that as a group, marathoners are less introverted and have better mental health compared with non-athletes, which may aid them in coping and or even benefiting from the stressors inherent in marathon training.
Winker et al.	2010	To study the impact that intense endurance exercise may have on cognitive performance related to brain derived neurotropic factor and insulin-like growth factor in the elderly.	114	Quantitative Quasi-Experimental	This trial supports the hypothesis that intense endurance exercise training might be beneficial for maintaining cognitive functioning later in life although further research is needed.

Health Risks

Physical

Research has found a high incidence of carotid and peripheral atherosclerosis in marathon runners (Kröger et al., 2011; Möhlenkamp et al., 2008). In addition, marathon runners have been found to exhibit significantly higher systolic, diastolic, pulse, and mean arterial pressures, and arterial stiffness compared to controls (Kardara et al., 2011). While some of these risks are inherent in long-term vigorous activity, others are the result of training and/or overtraining. Prolonged strenuous activities such as training and participating in a marathon may lead to detrimental effects such as severe dehydration, electrolyte abnormalities, rhabdomyolysis, acute myocardial infarction, and sudden cardiac death (McCullough et al., 2011). The majority of marathon fatalities are caused by sudden cardiac arrest, indicated by an abrupt termination of cardiac activity with hemodynamic failure (Webner, DuPrey, Drezner, Cronholm, & Roberts, 2012). Approximately 65 - 70% of sudden cardiac deaths occur because of underlying coronary artery disease, while 10% are attributed to other structural heart diseases (Webner et al., 2012). Although hyponatremia and acute renal failure are rare, these conditions occasionally occur in marathon runners where several factors, including heat, stress, dehydration, latent myopathy, non-steroidal anti-inflammatory use, and viral/bacterial infection or chemical imbalances combine (Clarkson, 2007). The severe dehydration that can occur as a result of prolonged strenuous exercise, can lead to pre-renal azotaemia and be a precursor to acute kidney injury in a variety of settings (McCullough et al., 2011).

Many risks are the direct result of long training periods leading to overtraining injuries. Among marathon runners, knee injuries are the most common (Fredericson &

Misra, 2007). The most common musculoskeletal injuries were located in the knee, followed by the tibia/fibula and the lower back/hip (Ellapen, Satyendra, Morris, & Van Heerden, 2013). In a study done by Rudy and Estok (1983), women who ran over 40 miles a week have a significantly higher rate of developing stress fractures, hematuria, hip problems, menstrual irregularity, or amenorrhea. Activity-induced fatigue, more common in recreational runners than elite runners, can cause changes in cardiovascular function, neuromuscular control, metabolic availability, respiratory muscle function, locomotory muscle function, and central neural function (Bertram et al., 2013).

Current literature also indicated a relationship between exercise workload and upper-respiratory infection (Nieman, 2007). Due to the physiological stress that occurs during marathon training and running, the immune system may undergo changes that might affect respiratory function. These changes are linked to a rise in cortisol and growth hormones resulting from endurance exercise (Åkerström & Pedersen, 2007). Coupled with other marathon-linked stress factors such as lack of sleep, extreme mental stress, malnutrition and/or exposure to new bacteria, upper-respiratory infections may be more likely to develop during participation in a marathon (Nieman, 2007). It is likely the increased rate of infections among runners may be the result of strenuous exercise too soon after infection (Nieman, 2007). Furthermore, marathoners are at increased risk of developing allergic rhinitis (Robson-Ansley et al., 2012). Marathoners also are exposed to many outdoor inhalant allergens, and with the shift in breathing during exercise from nose to combined mouth and nasal breathing, there is a greater deposition of airborne allergens and unconditioned air to the lowest airways (Robson-Ansley et al., 2012). This change in breathing likely increases the marathon runners' chance of inhaling air pollutants during the race (El Helou et al., 2012).

Skin problems are common among the marathon running population. Helm, Helm, and Bergfeld (2012) noted that more than 20% of medical injuries occurring during marathons involve skin troubles, including blisters, clavi, nail dystrophy, subungual hemotoma, talon noir, chafing, and even pseudonodules, which are typically caused by wearing overly-tight athletic shoes (Helm et al., 2012). Most skin conditions that affect runners are caused by infections, inflammation, trauma, or environmental injuries (Mailler-Savage & Adams, 2006). Mailler-Savage and Adams (2006) reported that skin cancer is of concern for outdoor athletes, as cumulative exposure to UV radiation during training for and running a race can increase the risk for squamous- and basal-cell carcinoma and melanoma. They also stated that when temperatures are below freezing and wind-chill is high, runners risk developing frostbite.

Roberts (2007b) noted several factors related to maturation and running. First, while the benefits for youth runners largely mirror the benefits for adult runners, the theoretical risk of injury is more prominent during the rapid growth phase of adolescence (Roberts, 2007b). Another major risk he noted for junior runners was heat stroke; children are less heat-tolerant than adults, and more susceptible to heat stroke due to their surface-area to mass ratio and immature sweat mechanisms (Roberts, 2007b). Despite these risks, the author stated among the many thousands of marathon finishers under the age of 18 years old, there had been no significant medical injuries reported (Roberts, 2007b). Last, he advocates that runners under 18 years of age be allowed to participate in marathon training, as long as their social, academic, psychological, and physiological development is not disrupted (Roberts, 2007b).

The lead author, publication year, purpose of the study, sample size, study design, and study conclusion(s) for each article discussing physical health risks is represented in Table 6.

Table 6

Review Matrix for the Physical Risks of Long-distance Running

Lead Author	Pub. Date	Study Purpose	Sample Size	Study Design	Conclusion(s)
Albano et al.	2012	To investigate three male athletes who faced acute coronary thrombosis after completing the Boston Marathon.	3	Quasi-Experimental	Although regular exercise reduces the incidence of coronary atherosclerosis and decreases mortality after a myocardial infarction, vigorous exercise may increase the risk of sudden death and myocardial infarction in those diagnosed with coronary artery disease.
Betram & Prebeau-Menezes	2013	To analyze the gait characteristics of the marathon runner before, during and at the end of a race.	84	Quantitative	Most successful runners were able to sustain a running speed for the entire duration of the race. However, speed slowed for the slower runners during the race but the frequency-stride length relationship remained normal.
Briviba et al.	2005	To investigate whether a marathon or half marathon could modulate DNA damage, antioxidant capacity or the immune system in healthy recreational runners.	24	Quantitative Quasi-Experimental	An increase in oxidative DNA damage in lymphocytes and a decrease in antioxidant capacity, while oxidative stress markers were not affected during the marathon or half marathon race.
Chan-Dewar et al.	2010	To assess myocardial deformation in sub-endocardial and sub-epicardial layers of the left ventricle wall before and after running a marathon.	14	Quantitative Quasi-Experimental	Data indicated higher levels of strain in the sub-endocardium.
Clarkson	2007	To examine the literature for conditions that lead to rhabdomyolysis and acute renal failure in marathon runners.		Literature Review	The rare cases of acute renal failure in marathon runners may be a situation where several factors (heat stress, dehydration, latent myopathy, NSAID use, and viral/bacterial infection) in some combination result in acute renal failure.
Day & Thompson*	2010	To examine the long-term cardiac risks and benefits associated with marathon running.		Literature Review	Although sudden cardiac deaths associated with marathon running are very rare, precautions should still be taken in order to investigate prodromal symptoms.
Ekblom et al.	2006	To examine the incidence of self-reported infectious episodes and relate these numbers to training habits, race time, socioeconomic and demographic factors.	1694	Quantitative	This study did not support the theory that infection rates increase after intense long-distance running but did suggest that exercising too soon after an infection may result in an increased rate of infection.

Table 6
(continued)

Lead Author	Pub. Date	Study Purpose	Sample Size	Study Design	Conclusion(s)
El Helou et al.	2012	To study the environmental factors that have the maximal impact on marathon running performance.	1791972	Quantitative	The influence of air temperature had the greatest impact on human running capacity and adaptation.
Finn & Coviello	2011	To review the literature on myocardial infarction and sudden death in recreational marathon runners.		Literature Review	Recommendations for participating in vigorous activity are discussed as well as an emphasis on yearly screenings and evaluations for those who participate in marathons.
Fredericson et al.*	2007	To review the literature evaluating the epidemiology and etiology of marathon injuries and provide suggestions for future research.		Literature Review	More experienced runners are less prone to injury, with the number of years running being inversely related to incidence of injuries. A graduated training program helps prevent injuries. Knee injuries are the most common seen in marathon runners.
Helm et al	2012	To review the common skin problems in long-distance runners.		Literature Review	Over 20% of medical injuries in marathons are related to the skin; Medical treatments are available.
Holloszy*	1977	To study the adaptations to endurance exercise training that make it possible for an individual to run 26.2 miles at an 11 to 12 mph pace.		Literature Review	The adaptive increase in the working muscle cells of trained as compared to untrained individuals. The adaptive increase in the capacity to oxidize fatty acids also results in a greater reliance on fat oxidation for energy during work of the same relative intensity in the trained state; this helps to protect against depletion of glycogen stores.
Ketelhut*	1996	To assess cardiovascular risk factors in marathon runners with different degrees of fitness.	30	Quantitative Quasi-Experimental	At the extreme end of a continuum such as represented by well-conditioned, middle-aged marathon runners, cardiovascular risk factors are related to the degree of fitness, as measured by the marathon running time.
Khosla	1982	To perform a study on the slow resting heart rate of long-distance runners with more than 50 cases.	103	Quantitative Quasi-Experimental	Resting pulse rate declines in athletes subject to training, and this is advantageous to completing a marathon in a low time. Its importance as an indicator of health and mortality has been neglected in recent epidemiological studies.

Table 6
(continued)

Lead Author	Pub. Date	Study Purpose	Sample Size	Study Design	Conclusion(s)
Legaz-Arrese	2011	To study the impact of exercise intensity on the release of cardiac biomarkers in marathon runners.	14	Quantitative	Exercise intensity influences the release of cTnI but does not influence NT-proBNP. Competitive running is needed for cTnI to be elevated.
Luke et al.	2010	To investigate whether long-distance running causes irreversible articular cartilage damage.	20	Quantitative Quasi-Experimental	Runners showed elevation in T1p T2 values after a marathon race, which indicated biochemical changes in articular cartilage.
Mailler-Savage & Adams	2006	To investigate the skin manifestations found in runners.		Literature Review	Epidemiology, origin, characteristics, treatment, and prevention of skin diseases specific to runners are discussed.
Matthews et al.	2012	To investigate whether the increase in marathon participation from 2000-2009 has affected the mortality rate and performance.	25	Quasi-Experimental	The rate of mortality and overall performance has remained unchanged from 2000-2009.
Mccullough et al.	2011	To study the impact that marathon running has on kidney function.	10	Quantitative	The data collected suggests that the physiological stress imposed in recreational runners during a marathon may interfere with sirtuin expression and weaken the expression of apoptosis.
McKune et al.	2005	To investigate the influence of ultra-endurance exercise on immunoglobulin isotypes and subclasses.	11	Quantitative Quasi-Experimental	In ultra-endurance runners, there were alterations in immunoglobulin concentrations after a race which indicated an enhanced immune response.
Minns et al.	2011	To examine electrocardiograms (ECGs) before and after a marathon race in order to characterize the changes that occur.		Quantitative	The most common change was atrial enlargement. However the significance of this data is unclear.
Nieman	2007	To review the risks of upper respiratory tract infections URTI during marathon training and after competition.	87	Quantitative Non-Experimental	Data indicates that there is a relationship between exercise workload and infection. Most endurance athletes URTI risk is unaltered in regular training; however URTI risk rises during periods of overtraining and competition

Table 6
(continued)

Lead Author	Pub. Date	Study Purpose	Sample Size	Study Design	Conclusion(s)
Noakes*	1987	To study the 36 cases of heart attack or sudden death in marathon runners for history of heart disease or sudden death in marathon runners for history of heart disease or coronary risk factors.	36	Quantitative Non-Experimental	Marathon runners, especially those with a family history of heart disease and other coronary risk factors, should not consider themselves immune to either sudden death or to coronary heart disease.
Nudel*	1989	To study the physiological and psychological characteristics and the running histories of young marathon runners.	16	Quantitative Non-Experimental	Runners had high physical fitness and no growth retardation.
Pedersen & Akerstrom	2007	To investigate the incidence of upper respiratory tract infections (URTIs) following marathons.		Literature Review	The susceptibility to URTIs following a marathon race or hard training has been linked to immune changes that occur with long intense exercise durations.
Predel	2014	To understand the controversy concerning middle aged athletes participating in endurance exercise and the cardiovascular adaptation and risk.		Literature Review	Long-term intense endurance exercise may pose adverse functional and morphological cardiac adaptations to middle aged runners. Therefore, optimal dose per pupil is still important to consider.
Rasmussen et al.	2013	To investigate if the risk of injury declines with an increase in running volume before a marathon race.	662	Quantitative	It is advised that runners run a minimum of 30km a week before participating in a marathon in order to reduce risk.
Roberts	2007	To review current literature on the safety of running a marathon <18 years old.		Literature Review	Children who choose of their own accord to participate in marathon training should be allowed to do so as long as their social, academic, psychological and physiological development is not disrupted.
Roberts et al.	2012	To investigate sudden cardiac arrest (SCA) and sudden cardiac death (SCD) in men and women.	2	Quantitative Quasi-Non-Experimental	As more women are participating in marathons, the difference between men and women's incidence of SCA and SCD is become more profound. Men's incidence has increased to 1 in 22,000 for SCD and 1 in 50,000 for SCA.

Table 6
(continued)

Lead Author	Pub. Date	Study Purpose	Sample Size	Study Design	Conclusion(s)
Robson-Ansley	2012	To study the prevalence of allergy and upper respiratory tract symptoms in runners of the marathon runner.	208	Quantitative	The prevalence of allergies within marathon runners in higher than the general population and those that had a positive score on the Allergy Questionnaire for Athletes were also more likely to suffer upper respiratory symptoms.
Schwellnus	2007	Does evidence support that exercise associated muscle cramping EAMC is related to serum electrolyte changes, dehydration, metabolic abnormalities or environmental extremes in marathon runners?		Literature Review	The development of premature muscle fatigue appears to be a more plausible explanation for EAMC and evidence in support of this hypothesis is accumulating.
Sheppard	2012	To determine the underlying causes of sudden death in long-distance marathon runners.		Literature Review	In order to understand the reasons for sudden death in athletes, pathologists should be aware and take precautions in order to understand the common and uncommon cardiac conditions that may lead to premature death.
Vierck et al.	2012	To examine the influence of endurance exercise on the antioxidative status of human skin.	9	Quantitative	Physical exercise performed outside leads to oxidative stress in the skin, which may increase the risk of sun exposure-induced damage.
Webner et al.	2012	To understand the risk of sudden cardiac arrest in marathoners in order to assist with emergency planning.	88	Quantitative	Sudden cardiac arrest occurs in 1 in 57,000 marathon runners with a higher prevalence in older males. Emergency planning was discussed in order to include medical staff throughout the race course.
Weibel*	2007	To determine the magnitude of ketone production in ultra-marathon runners and what affect if any this has on performance.	31	Quantitative Non-experimental	Two runner sub-populations were revealed, runners who produce ketones, and runners who do not. The level of ketones produced did not affect overall distance run. Although ketones did not affect race performance, long term health consequences are unknown.
Wilhelm et al.	2012	To investigate the long-term consequences of marathon running on cardiac remodeling and arrhythmias in the right heart.	122	Quantitative	Marathon running was not associated with right ventricular enlargement, dysfunction or ventricular ectopy.

Table 6
(continued)

Lead Author	Pub. Date	Study Purpose	Sample Size	Study Design	Conclusion(s)
Williams*	1996	To examine the dose-response relation in women between risk factors for coronary heart disease, particularly the concentration of HDL cholesterol, and vigorous exercise at levels that exceed official guidelines.	1837	Quantitative	Substantial increases in HDL cholesterol concentrations were found in women who exercised at levels exceeding current guidelines; higher HDL cholesterol concentrations could provide added health benefits to these women.
Xiang et al.	2014	To evaluate the effects of the intense exercise on the Th1/Th2 gene expression from the peripheral blood mononuclear cells of marathon participants.	16	Quantitative	Findings suggest that a Th1/Th2 imbalance in immunity offers a rationale for the increased risk of upper respiratory tract infections reported after intense exercise.
Yared & Wood	2009	To examine the evidence concerning whether marathon running is hazardous to cardiovascular health.	102	Quantitative	There is not enough qualitative evidence to imply that marathon running leads to the development of dangerous substrates for coronary events.
Zeigler	1991	To examine the perceived benefits of marathon running in males and females.	402	Quantitative Non-Experimental	Recreational runners were more likely to perceive benefits from running when compared to competitive runners. Women felt that running helped them develop a positive self-image while men reported running as more beneficial to them in regards to decreasing anxiety.

Non-physical

Of the included studies that examined the non-physical health risks of marathon running, several investigated the occurrence of psychological disorders such as depression and anxiety among marathon runners (Williams, 2009c). Participating in obsessive-compulsive running, as may happen to a person addicted to running, may cause strained relationships due to neglecting family or work responsibilities to pursue exercise (Estok & Rudy, 1986). Withdrawal symptoms, including negative mood and agitation may occur when runners are unable to exercise or train, with more severe withdrawal symptoms, such as anxiety or depression often occurring after the second week of non-training (Leedy, 2000). The runner’s exercise dependence may result in pursuing exercise patterns despite a persistent or recurrent physical or psychological problem caused or exacerbated by the exercise itself (Leedy, 2000).

Memory also may be impacted by the stress of marathon running. When runners were given implicit and explicit memory tasks before and following a marathon, explicit memory was impaired to a level seen in patients with amnesia and organic brain damage (Eich & Metcalfe, 2009).

The lead author, publication year, purpose of the study, sample size, study design, and study conclusion(s) for each article discussing non-physical health risks is represented in Table 7.

Table 7

Review Matrix for the Non-physical Risks of Long-distance Running

Lead Author	Pub. Date	Study Purpose	Sample Size	Study Design	Conclusion(s)
Allegre*	2007	To examine the relative influence of individual factors and environmental context of physical activity on exercise dependence.	95	Quantitative Quasi-Experimental	The strongest predictors of exercise dependence were individual factors (age and BMI). Exercise dependence could provide interesting insights into the promotion of physical activity as a health-related behavior.
Hassmen & Blomstrand	1991	To study mood change in marathon runners using the Profile of Mood States (POMS) before and after the 1989 Stockholm Marathon.	106	Quantitative Quasi-Experimental	Participation in a marathon race effects mood strongly in a more negative way when compared to regular moderate exercise does.
Leedy*	2000	To measure the anxiety and depression traits for a heterogeneous group of runners. Included are the runner's motivations for running and their training patterns.	276	Quantitative Non-Experimental	The study provides an indication that high levels of commitment to running need not be associated with dependency or addiction type problems. The most highly committed runners are strongly motivated by health benefits, and have more positive mental traits than do the least committed runners.
Nudel*	1989	To study the physiological and psychological characteristics and the running histories of young marathon runners	16	Quantitative Non-Experimental	The relatively high incidence of severe psychological disorders possibly suggests a need for psychological screening for young children entering a strenuous running program.

CHAPTER SEVEN: DISCUSSION

Regular rigorous exercise that occurs in any marathon-training program benefits cardiovascular health by lowering resting heart rate (Khosla & Campbell, 1982), improving HDL cholesterol (Williams, 1996), and reducing the incidence rate of coronary atherosclerotic disease (Albano et al., 2012). As runners train their bodies to withstand the physical demands of intense training, they also are conditioning their cardiovascular system to operate efficiently. In fact, there is a strong inverse correlation between mileage/ week and prevalence of diabetes, hypertension, and hypercholesterolemia, which also may explain why marathon participants indicated a lower use of LDL cholesterol-lowering medications and antidiabetic medications, especially amongst female runners (Williams, 2009a).

Marathon running can be a useful tool for weight management, bone loss mitigation, and a reduction in the rate of developing metabolic disorders. As marathon runners age and continue to participate in vigorous activity, they are less likely to develop metabolic disorders such as hypertension, diabetes, and high cholesterolemia (Williams, 2007). Research indicated that although bone density declines with age, the effects of marathon training can ameliorate the pace of bone loss (Drysdale et al., 2007). Exercise throughout life is critical to sustaining a healthy lifestyle, preventing a variety of diseases, and prolonging life expectancy (Predel, 2014). In fact, individuals who partake in more vigorous activity than the minimum recommendations have a longer life expectancy (Ruiz et al., 2014). Marathon runners can continue to participate in events as their age advances, gaining benefit despite their age. In fact, behavioral factors play a greater role in deteriorating physical performance than age itself (Leyk et al., 2009). Behavioral factors that influence physical performance may include sedentary behavior, smoking, and lack of proper nutrition, each of which is checked against in a marathon training regimen.

While relatively little research has been conducted on the non-physical benefits of marathon training, substantial evidence indicated that psychological and cognitive functioning is improved in long-distance runners. This may be due to increased circulation to parts of the brain that support cognitive functioning, and the positive impact running has on mental health. When engaging in a training regimen for a marathon, runners gain confidence and a sense of accomplishment. In 1991, Ziegler analyzed the perceived benefits of marathon running for both male and female runners. Males tended to primarily perceive the benefits of exercise in context of its physical components, especially related to increased energy, improved muscle tone, and an understanding of their physical capabilities. He also reported that running decreased levels of anxiety and increased their sense of identity; females, in contrast, felt that running had a positive effect on their self-image and improved their lives as a whole, and placed less emphasis on the physical components related to running.

The risks associated with marathon and long-distance running stem from the extensive amount of training required. The vigorous activity associated with such levels of training is generally beneficial to physical health, but prospective marathon runners may increase their risk of injury when not training adequately (Rasmussen et al., 2013). More experienced runners are less prone to injury. In fact, the number of years running is inversely related to incidence of injuries (Fredericson & Misra, 2007), though this correlation may be due to the *selective survival* phenomenon, where individuals quit running *because* they were injured. Thus, it is possible that those who have ceased marathon running due to knee injuries are unaccounted for among samples of "experienced runners," biasing the sample toward non-injury. Unlike elite athletes who are generally healthy and medically supervised by experienced trainers, recreational runners hail from diverse demographics across all age groups (Predel, 2014). Of these recreational runners, fitness levels and genetic predisposition to certain health related injuries and diseases vary widely. Therefore, medical screening should be encouraged, and should include a family history report, a physical examination and an electrocardiograph to detect coronary artery disease (Predel, 2014).

Exercise promotes health and well-being, but marathon running still poses a risk for cardiac arrest and mortality. The risk of sudden cardiac arrest is very low; it occurs in approximately 1 in 57,000 runners, with the majority of cases reported in older males (Webner et al., 2012). When comparing men and women's rates of sudden cardiac arrest, Roberts and Lunos (2012) found female marathoners to have sixfold lower risk than their male counterparts, but the disparity is not well understood. The rates of cardiac arrest and death have risen over the past decade, possibly because of the overall increase in the number of participants (Van der Wall, 2012). Moreover, current cardiovascular risk factors and/or a family history of cardiovascular disease might increase the risk of sudden death when performing extended vigorous activity. According to Noakes (1987), "[i]t is important for all marathon runners, especially those who have a family history of heart disease or other coronary risk factors to understand that they are not immune to sudden death" (p. 187). The risk of a life-threatening event is miniscule, but the importance of physician consultation for marathon runners cannot be overstated.

There has been a long held belief that there is an increase in upper respiratory infection rates in runners after exhaustive long-distance exercise (Nieman, 2007; Robson-Ansley et al., 2012). However, this theory fails to take into account the other health risks involved for individual marathoners, including lack of sleep, lack of adequate nutrition, exposure to harmful pathogens, and mental or physical stressors that may occur before or after a marathon (Nieman, 2007). Therefore, individuals who complete a marathon should be aware of their current health status and take measures to heal from severe illness before completing rigorous training or marathons.

The variance of event-specific entry requirements makes a minimum age difficult to isolate, but many thousands of minors have raced in marathons (Roberts, 2007b). The long-term effects associated with children and marathon running are still under-researched. Evaluation for cardiac risks and physician consultation for minors should occur. Instruction regarding nutrition and proper training also should not be neglected when working with young marathoners. Because of the uncertainty involved, when minors are allowed to participate, race officials should monitor them closely for signs of injury.

While the current literature is quite clear concerning the physical health benefits and risks resulting from marathon running, it is less clear about the non-physical health risks. Where some posit marathon runners as having high levels of affective mental health and healthy levels of commitment, others assert that such runners exhibit exercise dependency, and even experience addiction-like withdrawal symptoms when unable to train. Runners will often describe a feeling of euphoria following a run, associated with elevated mood. Deprived of regular running, the individual may noticeably miss this euphoric feeling. In short, among the relatively few studies examining the non-physical health effects of marathon and long-distance running, there is an absence of consensus on how marathon running impacts mental health.

Health is not restricted to physical and mental dimensions; its spectrum spans social, spiritual, emotional, intellectual, occupational, environmental and physical sections of life (Miller & Foster, 2010). Consequently, it is difficult to truly understand the health benefits and risks of long-distance running with a narrow focus of a select few dimension of health. Examining long-distance running requires an understanding of its impact on each facet of health and their synergy. Given the regular, intense training necessary to train for and complete a marathon, physical health is obviously *directly* influenced. However, because of the time and effort necessary to prepare for a marathon, it is likely that other aspects of one's health are *indirectly* influenced to varying degrees. Since optimal wellness represents balance between all components of health, it is important that future research determine how long-distance running impacts the non-physical dimensions of health.

CHAPTER EIGHT: LIMITATIONS

It is possible that the articles included in this review are not completely exhaustive of the literature on long-distance running. According to the exclusion criteria, articles that failed to specify a distance were disregarded. It is possible that some of these articles pertained to long-distance running, but if a distance was not stated in the keywords or the text, the article was not included. By searching only scientific journals, other representative literature that was not peer reviewed was excluded. For example, publications such as *Runner's World* magazine, an outlet that often publishes the findings of many well-respected and knowledgeable experts, fell outside of the search parameters. It also is possible that the key terms utilized failed to return all relevant articles.

CHAPTER NINE: FUTURE DIRECTIONS

Although this review did find that long-distance running can be an effective means of preventing chronic disease, several gaps in knowledge were identified. Further research is needed in the following areas:

a) The effects of marathon and long-distance running on non-physical areas of health (including the social, emotional, intellectual, spiritual, occupational, and environmental impact),
b) The effect of long-distance running over the runner's lifespan,
c) The difference of the impact of long-distance running for males and females, and
d) The unique effects of long-distance running on persons under the age of 18.

First, while a few articles presented studies focused on the emotional health of the marathon runner, they communicated a lack of thorough understanding regarding the mental health of marathon participants. Furthermore, understanding how marathon runners balance everyday life and the rigors of marathon running may help to promote exercise adherence for the general population. Social and familial ramifications were discussed, but further research should be conducted to allow the general population to understand how participating in a marathon may impact present and future relationships.

Another dimension of wellness noticeably absent from the research was the impact a runner's career and occupational health may have on marathon running. This focal point should include examinations of marathon running's relationship to vocational responsibilities. Specifically of interest is whether or not the skills developed during marathon running cross over into useable vocational applications.

Second, relatively few longitudinal studies examine marathon and long-distance-runners, with a significant drought employing a control or comparison group. As the number of participants engaging in marathons is growing each year, the long-term consequences of marathon running should be of concern for participants and health care professionals who provide care to them. In addition to the consequences of training, benefits of long-distance running over a lifetime should be explored. The differing health benefits and risks between elite runners and recreational runners indicated that proper training and medical guidance provide a framework that leads to fewer undesirable outcomes and improved health benefits. It is possible that many recreational runners lack access to the education, experience, and intense training regimen among elite runners. Therefore, they may be more prone to injury or mortality. Remarkably little research on this disparity surfaces in the literature. The dramatic influx of recreational runners who may lack understanding of the risks involved in their training and the long-term effects of such rigorous activity spurs the need for increased educational opportunities and more exhaustive screening procedures. When it comes to sudden cardiac arrest, 65% - 70% of the cases were due to underlying coronary artery disease (Webner et al., 2012). This indicates that all runners should speak with their healthcare provider before engaging in a marathon event, but it is unknown whether recreational runners do so. Education on the health benefits or risks involved in completing a half-marathon or marathon could be provided at a race or incorporated into the pre-race packet pick-up procedures.

Third, despite the fact that female runners now account for nearly half of the marathon running population, the current research has primarily focused on male runners. Limited literature investigating the health effects of marathon running exclusively for women reports lower rates of cardiac events for female runners. The reasons for the disparity in cardiac events are not understood, and there may be other gender-specific health risks or benefits to be discovered.

Fourth, there is no minimum age requirement for marathon participation and persons under the age of 18 are known to participate. The unique effects of long-distance running for persons whose bodies are still growing and developing have not been fully examined and require further study before recommendations can be made regarding minors and regular long-distance running.

CHAPTER TEN: CONCLUSION

The objective of this review was to systematically evaluate the physical and non-physical health risks and benefits of marathon running. Compelling evidence shows the effectiveness of regular physical activity in the primary and secondary prevention of several chronic diseases (e.g., cardiovascular disease, diabetes, cancer, hypertension, obesity, depression, and osteoporosis) as well as the prevention of premature death (Warburton, Nicol, & Bredin, 2006). Nevertheless, long-distance running is not without risk. In fact, long-distance runners show a higher rate of carotid and peripheral atherosclerosis and arterial stiffness along with a higher incidence of knee injuries (Kardara et al., 2011). Despite the possibility of sudden kidney failure or cardiac arrest, most severe injuries and health problems occur due to improper training.

Even with his peak physical conditioning as a Greek soldier, by today’s standards the mythical Pheidippides would likely be considered a recreational runner. His legend is enriched by his death, but the lives of today’s distance runners ought to be protected by addressing the gaps identified in this review; they require further examination before properly understanding the balance of risk and benefit of the sport.

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