EFFECT OF MUSIC ON RUNNING PERFORMANCE AMONG RECREATIONAL RUNNERS: A SCOPING REVIEW

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EFFECT OF MUSIC ON RUNNING PERFORMANCE AMONG RECREATIONAL RUNNERS: A SCOPING REVIEW

by

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Thesis submitted in fulfillment of the requirements for the Degree of Bachelor of Health Sciences (Exercise and Sports Science)

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CERTIFICATE

This is to certify that the dissertation entitled Effect of Music on Running Performance Among Recreational Runners: A Scoping Review **i**s the bona fide record of review done by Ms Raja Nurzafirah Atiqah binti Raja Zaidi during the period of March 2020 until June 2021 under my supervision. I have read the dissertation and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation to be submitted in partial fulfillment for the degree of Bachelor of Health Science (Honours) Exercise and Sports Science.

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DECLARATION

I hereby declare that this dissertation is the result of my own review, except where otherwise stated and duly acknowledge. I also declare that it has not been previously and concurrently submitted for any other degrees at Universiti Sains Malaysia or other institutions. I grant Universiti Sains Malaysia the right to use the dissertation for research, teaching, learning and promotional purposes.

Raja Nurzafirah Atiqah binti Raja Zaidi
Date: 23 June 23, 2021

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EFFECT OF MUSIC ON RUNNING PERFORMANCE AMONG RECREATIONAL RUNNERS: A SCOPING REVIEW

ABSTRACT

Introduction: Music is one of the many mediums that can stimulate the mood, emotion, and improve atmosphere. These days, music is easily accessible through gadgets such as smartphones, MP3 and MP4s, and also through applications such as YouTube and Spotify. Many research has been done on the effect of music on performance among professional athletes. This review aimed to provide a synthesis from previous studies on effect of music on running performance among recreational runners. **Methods**: A comprehensive search of academic journals on this topic published from 2015 until 2021 was conducted. A total of 9 truly eligible studies were selected from 239 studies screened from electronic databases which included EBSCOhost, ScienceDirect, Scopus, and SpringerLink. **Results**: Fives studies investigated the effect of music on running cadence. Two studies reported that running cadence in music condition is higher than no music condition. Three studies also reported that running with high tempo music resulted in higher running cadence compared to running cadence in slow tempo music. One study reported that females has higher running cadence compared to males. In addition, there were four studies reported on running speed. Two studies reported that there is no effect in running speed, even though there is music stimulus. However, a study reported there is an effect in running speed in music condition compared to no music condition, and another study reported running speed is higher with high music tempo compared. In addition, a study reported running speed is higher when listening to

asynchronous music. A study also reported a faster running behaviour when participants were not instructed to match the tempo of music. Next, two studies reported on step length and running distance. A study reported step length is larger in uninstructed condition while another study reported step length and running distance increases when running to synchronized music. Three studies reported on heart rate, perceived exertion, blood lactate, and total time effort. All study found no difference on heart rate reading in no music condition and with music condition. One study reported on an increment of total time effort in music condition. One study reported an increase in rating of perceived exertion after anaerobic threshold intensity when running in music condition. While two other studies reported a lower rating of perceived exertion when listening to music and listening to synchronized music condition. A study reported on blood lactate and found an increment in blood lactate after anaerobic threshold intensity when running in music condition. Finally, one study reported on arousal and feelings and found that arousal score is higher in music condition, as well as feelings were more positive in music condition.

KESAN MUZIK KE ATAS PRESTASI LARIAN DALAM KALANGAN PELARI REKREASI : SUATU ULASAN PENSKOPAN

ABSTRAK

Pengenalan: Muzik adalah salah satu daripada medium-medium yang dapat merangsang mood, emosi, dan menambah baik suasana persekitaran. Hari ini, muzik mudah diakses melalui alat-alat canggih seperti telefon pintar, MP3 dan MP4, dan juga melalui aplikasi seperti YouTube dan Spotify. Banyak kajian telah dilakukan mengenai pengaruh muzik terhadap prestasi dalam kalangan atlet profesional. Ulasan ini bertujuan untuk memberikan sintesis yang terdapat daripada kajian-kajian sebelum ini mengenai pengaruh muzik terhadap prestasi larian dalam kalangan pelari rekreasi. **Kaedah**: Pencarian komprehensif jurnal akademik mengenai topik ini yang diterbitkan dari tahun 2015 hingga 2021 dilakukan. Sebanyak 9 kajian yang benar-benar layak dipilih dari 239 kajian yang disaring dari pangkalan data elektronik yang merangkumi EBSCOhost, ScienceDirect, Scopus, dan SpringerLink. **Hasil**: Lima kajian mengkaji pengaruh muzik pada irama larian. Dua kajian melaporkan bahawa irama larian dalam keadaan mendengar muzik lebih tinggi daripada keadaan tidak mendengar muzik. Tiga kajian juga melaporkan bahawa larian dengan mendengar muzik bertempo tinggi menghasilkan irama larian yang lebih tinggi dibandingkan dengan irama larian sewaktu mendengar muzik bertempo perlahan. Satu kajian melaporkan bahawa wanita mempunyai rentak larian yang lebih tinggi berbanding lelaki. Di samping itu, terdapat

empat kajian yang melaporkan mengenai kelajuan larian. Dua kajian melaporkan bahawa tidak ada kesan dalam kelajuan larian, walaupun ada rangsangan muzik. Walau bagaimanapun, sebuah kajian melaporkan terdapat kelakuan larian yang lebih pantas dalam keadaan mendengar muzik dibandingkan dengan keadaan tidak mendengar muzik, dan kajian lain melaporkan kecepatan larian lebih tinggi dengan mendengar muzik yang bertempo tinggi. Di samping itu, kajian melaporkan kelajuan lariann lebih tinggi ketika mendengar muzik yang mempunyai rentak yang selaras. Satu kajian juga melaporkan tingkah laku larian yang lebih pantas apabila peserta tidak diarahkan untuk menyesuaikan rentak larian dengan tempo muzik yang didengari. Seterusnya, dua kajian melaporkan mengenai jarak langkah dan jarak larian. Satu kajian melaporkan panjang langkah lebih besar dalam keadaan tidak diberi arahan sementara kajian lain melaporkan panjang langkah dan jarak berjalan meningkat ketika berlari sambil mendengar muzik yang diselaraskan. Tiga kajian melaporkan mengenai kadar denyutan jantung, tenaga yang dirasakan, laktat darah, dan jumlah masa usaha. Semua kajian mendapati tidak ada perbezaan pada bacaan degupan jantung terhadap larian tanpa keadaan muzik dan larian dalam keadaan bermuzik. Satu kajian melaporkan peningkatan jumlah masa usaha dalam keadaan muzik. Satu kajian melaporkan peningkatan penilaian aktiviti yang dirasakan setelah intensiti ambang anaerob ketika berlari dalam keadaan bermuzik. Sementara dua kajian lain melaporkan penilaian yang lebih rendah terhadap aktiviti yang dirasakan semasa mendengar muzik dan mendengar muzik yang tidak diselaraskan. Satu kajian melaporkan mengenai laktat darah dan mendapati peningkatan dalam laktat darah setelah intensiti ambang anaerob ketika berlari dalam keadaan bermuzik. Akhirnya, satu kajian melaporkan tentang gairah dan perasaan dan mendapati bahawa skor gairah lebih tinggi dalam keadaan bermuzik, dan juga perasaan lebih positif dalam keadaan bermuzik.

Table of Content

Chapter 1

Introduction

1.1 Background of the review

Music is one of the many mediums that can be used in many situations to stimulate the mood, emotion, and environment. According to Oxford Dictionary, music can be defined as sounds that are arranged in a way that is pleasant or exciting to listen to. These days, music is easily accessible through gadgets such as smartphones, MP3 and MP4s, and also through applications such as YouTube and Spotify. The effect of music has its benefits in our daily lives. For instance, music is used to manage stress and anxiety.

On a study conducted by Eslami, et al (2019) regarding the effect of music on the stress severity among the staff of surgery rooms where the subjects which are nurse scrubs were to listen to a laid instrumental music for 30 minutes for 5 times before going to the surgery room, it is proven that music could reduce stress in the surgery room staff. According to the study, the experiment group were to listen to music for five times, and the result shows significant changes compared to the control groups. This depicts the positive impact of music which can help to reduce stress.

Next, a study by Homel, et al (2017) where sixty patients who underwent spinal fusions were divided into experimental group and control group. The experimental group received one 30-minutes music therapy session during an 8-hour period within 72

hours after surgery. Based on the observational data from the study, it is depicted that both mood state and resilience in coping are enhanced through an ongoing relationship with music therapy.

Meanwhile in the world of sports, music is believed to have ergogenic effects that can promote motivation, as well as improve performance. Music is often used to motivate and inspire people to an important event as well as when they engage in sports and training for competition (Bonnette, et al, 2012). motivation typically results in an increase workload, thus depicts an enhanced performance. In addition, music has been shown to enhance positive affect, which bears strong influence on an individual's intention to exercise and adhere to an exercise programme (Sanchez, et al., 2014). Terry, et al. (2020) stated that stated that music contribute to ergogenic effects through elicits several interrelated benefits such as act as a stimulant, or as a relaxant. For instance, when used during physical activity, music has been can elicit positive affective states and distract exercisers or athletes from the unpleasant sensations associated with physical effort and fatigue.

In addition, music helps in synchronization, especially in choreography sports such as rhythmic gymnastics. According to Hallett and Lamont (2017), syncrhonization in walking was found to take place only when participants were instructed to move in time with auditory cues. Next, according to Van Dyck & Leman (2016), in scientific research, cyclists' covered distance, power, and pedal cadence could be increased by introducing music with faster tempi; while slower tempi were shown to lead to decreases in these measures. Thus, music with a fast tempo tends to act as an external psyching-up stimulus in repetitive endurance activities, while the opposite effect is obtained through the use of slow tempi. In addition, music motivates exercisers to

sustain the effort and at the same time distracts them from the sensation of fatigue from their bodies (Savitha, et al, 2013). According to other studies, music captures attention, raises spirits, triggers a range of emotions, alters or regulates mood, evokes memories, increases work output, heightens arousal, induces states of higher functioning, reduces inhibitions and encourages rhythmic movement (Karageorghis & Pries, 2012).

In this study, the effect of music on running performance will be studied on recreational runners. Recreational runners can be described as runners who run one to three times per week for six months for non-professional purposes. Runner's cadence, running speed, step lengths, running distance, heart rate, rating of perceived exertion, total time effort, and blood lactate are analyzed in this study.

1.2 Problem statement

Music is one of the tools or mediums that often used in sports' world among athletes to regulate mood and promote motivation to achieve optimum performance. Even though there are many studies about the effect of music conducted on professional athletes and runners, limited studies conducted on recreational runners and their running performances are available. However, the present study may figure out the effect of music by listening to it before running and run without music, as well as listening to differently manipulated music such as slowed down and accelerated music tempo at different angles. Therefore this study will examine the effect of music by listening to it while running.

1.3 Objective

i. To provide a synthesis from previous studies regarding the effect of music on running performance among recreational runners.

1.4 Research questions of review

i. Does running with music improves mood, emotion, and attention among recreational runners?

ii. Does running with music affect heart rate reading, blood lactate, and perceived exertion among recreational runners?

iii. Does running with music have an effect on running performance among recreational runners?

1.5 The hypothesis of the review

i. Running with music improves mood, emotion, and attention in recreational runners.

ii. Running with music has an effect on heart rate reading, blood lactate, and perceived exertion in recreational runners.

iii. Running with music does improve running performance among recreational runners.

1.6 Significance of the review

This review will provide a knowledge on the effect of music on running performance among recreational runners. In addition, the outcome of this review will discuss the application of music that can improve running performance among recreational runners.

Chapter 2

Literature Review

2.1 Effect of Music on Psychology

Music has an effect on psychology in exercise and sport settings where it can capture attention, lift spirits, generate emotion, change or regulate mood, evoke memories, increase work output, reduce inhibitions, and encourage rhythmic movement (Atan, 2013). In addition, music listening during sports activities is believed to capture attention, distract from fatigue and discomfort, and prompt and alter mood states (Van Dyck & Leman, 2016).

According to Barwood, et al., (2009), Bishop et al suggested that the right music can be used as a tool to 'psych up' in preparation for arousal regulation, shift attentional focus, boost self-efficacy, and encourage psychological skills usage such as mental imagery. For instance, in a study by Karageorghis, et al., (2013) where participants were to do a 200-m freestyle swimming in no music control condition, and two experimental trials, which are motivational music condition, and motivationally-neutral music condition reported that participants commented that music in both experimental condition enabled them to focus more effectively on the task or to dissociate from the pain induced by the all-out effort. Thus, this findings depicts that music can shift attentional focus. Participants also reported that the music had a positive influence on how they felt and that it was preferable to complete the task with music than without.

Furthermore, to support this finding, it was reported that music listening can be an effective dissociation strategy, reducing perceptions of effort and fatigue by up to 12% at low to moderate intensity exercises (Karageorghis, et al., 2012).

In a study by Stork, et al. (2019) where insufficiently active adult participants were to complete sprint interval training under three different conditions, which includes motivational music, podcast control, and no audio control reported that music has the potential to enhance feelings of pleasure, improve enjoyment, and elevate performance during the sprint interval training.

According to Karageorghis, et al. (2012) synchronous music use has been shown to provide ergogenic and psychological benefits in repetitive endurance activities. For instance, motivational synchronous music used during treadmill walking improved time to voluntary exhaustion by 15% compared with a no-music control condition. While asynchronous music act as a stimulant that influence arousal levels, which upbeat music will increase arousal while soft and slow music reduces arousal.

Listening to suitable music while exercising can prolong exercise duration and improve exercise performance. In addition, listening to music helps to make exercise session more enjoyable as it can distract from fatigue and discomfort.

2.2 Effect of Music on Physiology

Music has an effect on physiology where it regulates physiological changes when individuals performing in a certain intensity of exercises. For instance, it motivates exercisers to sustain the effort and at the same time distracts them from the

sensation of fatigue from their bodies (Savitha, et al, 2013). However, the ergogenic effect of music can be depends on the intensity of the exercise. Van Dyck, et al. (2016) stated that physiological cues seem to dominate the exerciser's processing capacity at high intensity levels, where when the workload becomes too high, the exerciser's attention is typically shifted towards the painful or fatiguing effects of the exercise. Hence, music tends to lose its power to influence work output. For instance, Dyrlund & Wininger (2008) stated that in a study conducted by Kendzierski and DeCarlo where participants were asked to ride an exercise bicycle for 30 minutes at steady and comfortable pace, it was reported that participants enjoyed the exercise more in listening to music condition than without music condition. It was also reported that low intensity is a comfortable pace for some participants while moderate intensity is a comfortable pace for more physically fit participants.

According to Stork, et al. (2015), a large body of research has shown that listening to music during exercise not only increases affect, improves enjoyment, regulates arousal, reduces perceived exertion, and improves motivation but also enhances exercise performance. For instance, according to Bonnette, et al. (2012), the previous research by Thornby et al. found that the time spent exercising, the amount of work done, and heart rate were all significantly higher in the presence of music than in the other conditions. Similarly, Edworthy and Waring make the suggestion, in regards to music's effect on running performance, that the pace of music will influence the pace of exercise. Therefore, the assumption can be made that exercising to fast-tempo music should produce faster running performance. However, in this study's case, where participants were to complete 1.5 miles run as fast as possible while with and without listening to music, the music selection was not controlled; therefore some participant's

personal preferences might not have met the tempo or vigorous nature of the exercise conducted. Even so, the results of the two trials found the subjects running performance while listening to music to be substantially faster than running performance without music listening (Bonnette, et al., 2012). Meanwhile, a study conducted by Savitha, et al. (2013) where the subjects are to exercise to music were able to exercise at lower heart rate with music compared to no music during the exercise period for the same intensity of exercise. Thus, the heart rate reserve and thus the cardiovascular efficiency would be higher while exercising with music. In addition, several studies have shown that exercising while listening to music decreased the perceived exertion levels and improved exercise performance when compared to exercising in silence during low and moderate-intensity exercises. (Savitha, et al., 2013).

Ergogenic effect of music that regulate physiological changes can lead to a better exercise performance. According to Van Dyck, et al. (2016), music listening during sports activities is believed to increase arousal, relieve stress, and evoke a sense of power and produce power-related cognition and behavior.

Chapter 3

Methodology

3.1 Data sources

Related studies were searched electronically using the following databases: EbscoHost, ProQuest, Sage Journals, Science Direct, Scopus, and Springer Link. Briefly, the selected studies were hand searched using the same selection criteria as described below. In addition, cross-referencing on related previously published study was performed to obtain additional information. Peer-reviewed articles in English language from January 2015 until January 2021 were used. No attempts were made to contact authors for additional information. Comparable searches were made for the other databases.

3.3 Study selection

The search was conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. The following keywords were used during the search: #effect of music, #ergogenic effect of music, #running performance, and #recreational runners, #recreational running. Studies were screened for employing effect of music as intervention, and running performance as outcome measures or stimulus. Controlled trials and laboratory studies were included in this review. The

intervention comprised of the use of music. Running performance as: (1) running with and without music , (2) instructed running and uninstructed running, (3) running to synchronous music and asynchronous music, or (4) running in hot and humid weather.

3.3 Data extraction

The titles and abstracts of retrieved articles were reviewed using the criteria specified to determine whether full-texts were required for further analysis, which is each full-text manuscript was evaluated systematically according to the study: (1) objective/s, (2) characteristics of the study (study design, participants, age and sample size), (3) contents of intervention (intervention types, length of intervention or mode of exercise tested (4) targeted outcome/s, and (5) main findings. The outcomes extracted from those studies were not combined, re-analysed or changed due to the nature of this systematic review.

3.4 PRISMA FLOW

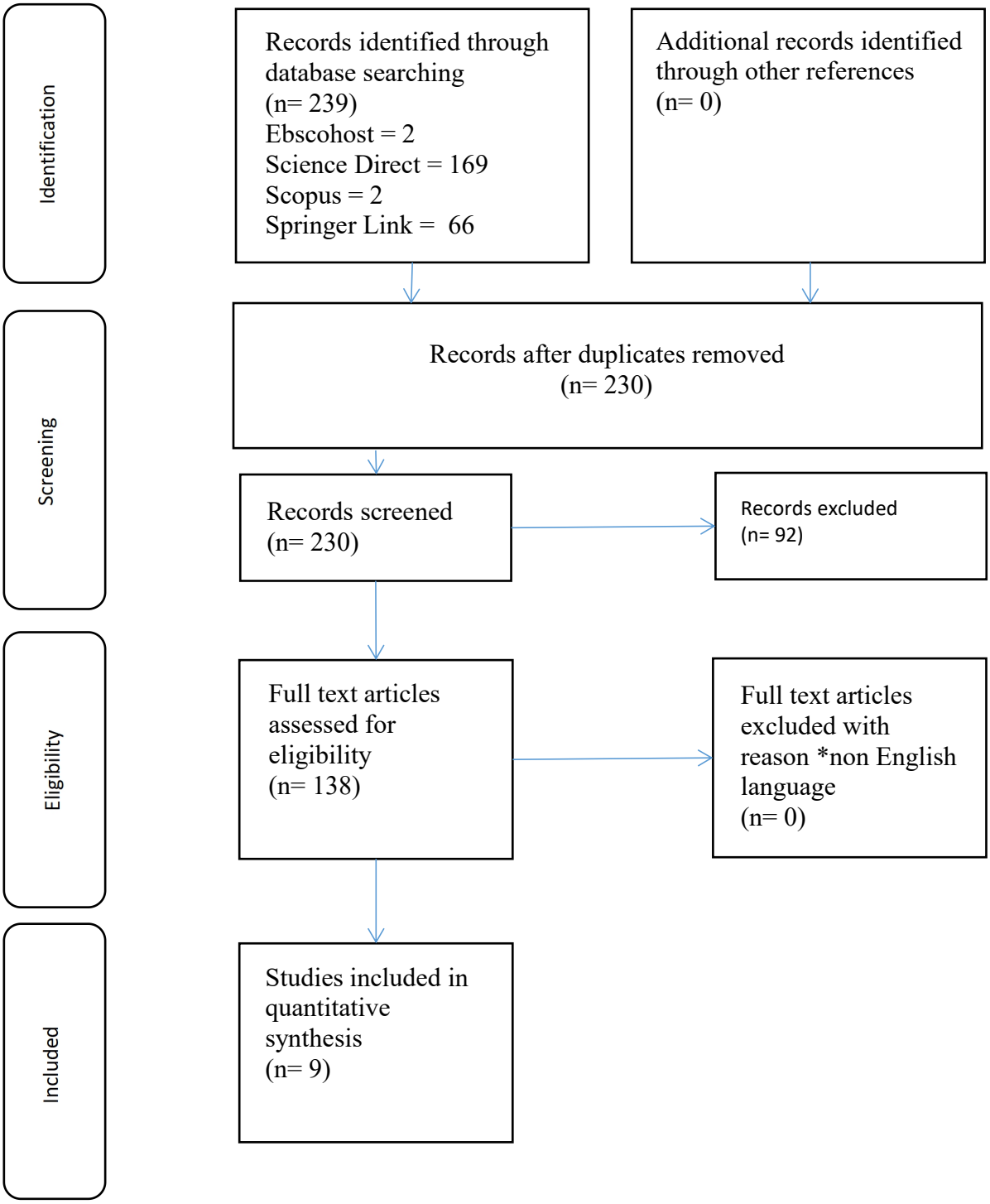

Figure 1 PRISMA flow for study selection

Chapter 4

Results

4.1 Search results

A total of 239 potential articles were retrieved from four databases. After removing duplicates, 230 articles were evaluated based on the titles and abstract against the selection criteria. A total of 92 articles were excluded for not investigating effect of music on running performance and the participants involved in the study were not people who run for recreational purposes. After a detailed analysis of the remaining full-text articles, only 9 truly eligilbe articles were included in this scoping review. This is because, only 9 studies on music found are related to either running performance and recreational runners. Figure 1 describes the PRISMA flow diagram for study selection.

From the 9 studies reviewed, all studies involved recreational runners, and people who run for non-professional purposes, or people who run at least once a month. From the included articles, one study related to incremental running on a treadmill (Rasteiro, et al, 2020), one study related to running on a treadmill in climatic chamber (Nikol, et al, 2018), and seven studies related to running on running tracks (Van Dyck, et al, 2015; Buhmann, et al, 2018; Van Dyck, et al, 2021; Buhmann, et al, 2017; Kawabata & Chua, 2020, Lorenzoni, et al, 2019; Ramji, et al, 2016). All of the 9 articles that were selected and included at the final stage of the screening in this scoping review are experimental studies.

Types of music used in exercise

All of the nine studies used music with 120 bpm to 200 bpm, which are suitable for running. Of the nine studies found in this review, three studies experimented with high and low music tempo. Van Dyck, et al (2015) used low and high music tempo as lowest as -3.00% and as high as +3.00% of the original one. While the tempo used by Buhmann, et al (2017) was increased and decreased by 5%. In addition, Lorenzoni, et al (2019) experimented with music tempo 30% higher and lower from initial runner's running cadence.

Effect of music on running cadence

Table 1 summarizes the effect of music on running performance. Five studies involved participants who were to run at their comfortable pace (Van Dyck, et al., 2015; Buhmann, et al., 2017; Buhmann, et al., 2018; Lorenzoni, et al., 2019; Van Dyck, et al., 2021). Three studies reported that, there is a significant difference between running without music and running with music. Running cadence without music was reported to be lower than running cadence while listening to music (Van Dyck, et al., 2021). In addition, Van Dyck, et al. (2015) reported that listening to the fast-tempo music resulted in increased running cadence and slow-tempo music resulted in decreased running cadence. This finding is supported by a study done by Buhmann, et al. (2017) where cadence in a low relative phase angle adjustment of music showed that running cadence was increased compared to control.

Studies by Buhmann, et al (2018) and Van Dyck, et al. (2015) found no differences in terms of change of cadence between male and female participants. However, Van Dyck, et al. (2021) revealed that female participants had higher running cadence compared to male participants. In addition, in a study conducted by Van Dyck, et al. (2021) where participants were given instructions either to match the cadence with music or not to, it was reported that cadence between instructed condition and uninstructed condition is the same as there is no difference in cadence in both conditions. However, running cadence in both conditions is higher than running cadence in no music condition. Lorenzoni, et al. (2019) conducted a study about the effect of manipulating music tempo on running cadence. It is revealed there is no difference on running cadence in slow music tempo and fast music tempo. However, to compare both conditions with no music control condition, synchronization to music has an effect on running cadence.

Effect of music on running speed

Four studies investigated the effect of music on running speed. Buhmann, et al. (2018) conducted a study on synchronizing running to music and found that there is no difference in running speed in each manipulated music synchronization. However, Van Dyck, et al. (2021) reported that there is a faster running behaviour when participants were not instructed to match their cadence to music compared to no music and instructed conditions. A finding by Buhmann, et al. (2017) reported that running speed with fast music tempo is higher than music control which participants matched their foot falls to the beat of music. In contrast to these studies, Lorenzoni, et al. (2019) reported that even though there is manipulation on music stimulus, it was found that there were no changes in running speed as participants were requested to keep a

constant speed throughout each running session. Interestingly, in a study on synchronous and asynchronous music by Ramji, et al. (2016) it is reported that participants ran faster than the tempo in all asynchronous conditions.

Effect of music on step length and running distance

In a study on instructed versus spontaneous entrainment, Van Dyck, et al. (2021) reported that step length is larger in uninstructed condition compared to instructed and no music conditions. However, the same study reported that footfalls were more closely matched musical beats in instructed condition compared to uninstructed condition. In addition, listening to synchronized music increases step length and running distance compared to listening to asynchronized music (Ramji, et al., 2016).

Effect of music on heart rate, perceived exertion, total time effort, and blood lactate

Three studies studied the effect of music on running performance and measured heart rate, perceived exertion, total time effort, and blood lactate. In a study conducted by Rasteiro, et al. (2020), there was no significant difference on heart rate between no music condition and music condition. However, it was reported that there was an increment in total time effort when listening to music during the incremental running test. In addition, the study found that when running with music, blood lactate and perceived exertion was increased after anaerobic threshold intensity compared to running without music.

In a study on the effects of asynchronous music and running performance, Kawabata & Chua (2020) reported that there was no difference of heart rate between

music condition and no music condition. However, heart rate was significantly higher during 20 to 30 minutes into running compared to 0 to 10 minutes into running in both conditions. In addition, it was reported that rating of perceived exertion scores was lower in music condition compared to no music condition. The same study also found that the rating of perceived exertion scores was higher during 15 to 30 minutes into running compared to 5 to 10 minutes into running in both conditions.

Nikol, et al. (2018) studied on the effect of synchronous music and running performance in hot and humid conditions and found that heart rate reading was slightly lower at 15 minutes into running in synchronous music condition compared to no music condition. The study also reported that perceived exertion was lowered in synchronous music condition compared to no music condition, even though participants completed the same workload in both conditions.

Rasteiro, et al. (2020) found that the adjustment of cadence to music tempo, an increase in blood lactate, heart rate, and perceived exertion is more pronounced in female participants.

4.2 Table of result

Table 1: Effect of music on running performance among recreational runners.

No.	Authors and year	Study target/target population	Intervention/exercise program	Outcome measures	Main finding
1.	Van Dyck, E., Moens, B., Buhmann, J., Demey, M., Coorevits, E., Dalla Bella, S., & Leman, M. (2015) Spontaneous Entrainment of Running Cadence to Music Tempo	16 healthy adult participants (9 females), with an average age of 22.25 years, reported to be fit to run about 10km.	Each participant was asked to run at their own comfortable tempo on a 200-m running track for four laps continuously, for 12 times with 5 minutes break after each set of four laps by listening to the self-selected motivational music. Participants ran 4 laps consisted of running without music (first lap), running at self-paced cadence without musical accompaniment (second lap), running with music adjusted according to the 11 tempo-changed condition (third and fourth laps). In each of the 11 four-lap sequences, a different condition was tested. During the two final laps with tempo-changed music, the music tempo was adjusted to either −3.00, −2.50, −2.00, −1.50, −1.00, 0.00, +1.00, +1.50, +2.00, +2.50, or +3.00 % of its original one, played during the second lap.	Degree of cadence (increase/decrease); the first 5s and the final 20s of the laps with tempo-changed music were discarded and ignored.	There is a significant relationship between imperceptible alterations in music tempo, in proportion to recreational runners' self-paced running cadence, and cadence adaptation; faster music resulted in an increase, while slower music led to a decrease in running cadence. A significant decrease in the level of entrainment in combination with increasing deviations from the original music tempo. No significant relationship between perceived exertion and entrainment. Female participants have higher levels of tempo entrainment compared to male participants.
2.	Buhmann, J.,	36 healthy adult	A music database	Cadence and	There is a significant

	Moens, B., Van Dyck, E., Dotov, D., & Leman, M. (2018). Optimizing beat synchronized running to music.	participants (19 males, 17 females), who are recreational runners capable of running 30 minutes continuously.	consisting of music tracks within tempo range of 120-200 bpm which rated as highly motivational for running were created. Participants were asked to run in solo conditions at their own comfortable pace for 5 minutes continuously, for six consecutive times on a 200m running. In each of the six 5-minutes running, a different alignment strategy was tested. Each of the 5-minute runs started with 25 seconds of silence, followed by five musical excerpts of 55s with an original tempo approaching the average cadence of the last seven footsteps, Participants were allowed to take a break for several minutes in which they rated their perceived exertion on the Borg Scale.	speed.	change in cadence when running in silence compared to running with music. For speed, it is reported that there is no significant difference in running speed.
3.	Rasteiro, F. M., Messias, L. H. D., Scariot, P. P. M., Cruz, J. P., Cetein, R. L., Gobatto, C. A., & Manchado-Gobatto, F. B. (2020). Effects of preferred music on physiological responses, perceived exertion, and anaerobic threshold determination in an	20 healthy, non-athletes, non-smoking and active male and female; active and experienced with at least two years of weekly practice in running exercise.	Incremental running test started at 7km/h with increments of 1km/h at each 3 minute stages, the slope of the treadmill was maintained at 1% during all tests. The effort was interrupted for 30 seconds for blood collection. During this interval, participants indicated with their fingers the perceived exertion in	Blood lactate [Lac], heart rate (HR), perceived exertion, total time effort (TT).	Most of the participants evaluated had a significant improvement in total time of effort in the presence of preferred music, where male shows 2-11% of improvement while female shows 2-20%. Moreover, it is depicted that blood lactate and perceived exertion are elevated

	incremental running test on both sexes.		two psychometric scales. The two sessions were randomized and separated by 48-72 hours.		after anaerobic threshold intensity determination for both sexes. In addition, women seem to be more susceptible than men to preferred music after anaerobic threshold intensity in terms of blood lactate, heart rate, and perceived exertion.
4.	Van Dyck, E., Buhmann, J., & Lorenzoni, V. (2021). Instructed versus spontaneous entrainment of running cadence to music tempo.	33 healthy adult participants who are recreational runners (15 males, 18 females), fit enough to run comfortably for at least 30 min without feeling exhausted, running regularly.	Participants were asked to run solo for four times for 4 minutes, and 5 minutes break were introduced after each 4 minutes running for a sufficient rest. Participants were asked to run at their self-paced cadence with no music during the first session. During the second session (uninstructed condition), participants run at their self-paced cadence with music with a tempo matching their cadence assessed during the last 120 steps taken in previous condition. During the third session (instructed condition), the same stimulus was presented yet participants were instructed to match their running cadence with the tempo of music.	Cadence, speed, step length, tempo entrainment, mean relative phase angle (rPA), resultant vector length (RVL).	Running cadence was significantly lower in the no music condition compared with the instructed and uninstructed. It also found that no significant difference between the instructed and uninstructed conditions. In step length, uninstructed condition demonstrated larger step lengths compared with no music condition and instructed one. It is reported that there was a faster running behaviour in the uninstructed condition compared to no music and instructed conditions. Tempo entrainment is significantly higher in the instructed compared with the uninstructed condition. It is reported that

					footfalls are more closely match musical beats in the instructed condition compared with the uninstructed one. RVL was shown to be significantly higher in the instructed compared with the uninstructed condition.
5.	Buhmann, J., Moens, B., Lorenzoni, V., & Leman, M. (2017). Shifting the musical beat to influence running cadence.	26 healthy adult participants (12 males) who are recreational runners and indicated to be capable of running 30 minutes continuously.	After a 4-minute warm-up and equipped, participants were asked to run solo at their own tempo on the 200m running track for 4 minutes continuously, for eight consecutive times. For the first run, participants ran to the isochronous metronome condition in which the music tempo was matched to the runner's preferred cadence. In each of the following seven 4-minute runs, a different music alignment strategy was tested and occur only once, which the tempo will be increased or decreased up to 5%.	Cadence, and speed.	Cadence changes were significantly higher when low relative phase angle adjustment of music at 25° than the music control, compared to other speeding up conditions. For speed, running speed is higher than the music control at low relative phase angle adjustment of music at 25°.
6.	Kawabata, M., & Chua, K. L. (2020). A multiple mediation analysis of the association between asynchronous use of music and running performance.	20 healthy recreational runners (10 males) who are physically active but not running more than three times a week.	Participants were asked to do a 5-minute light intensity warm-up followed by a 30-min moderate intensity continuous treadmill run with, and without music.	Affective valence, arousal - feeling scores (FS) & felt arousal scores (FAS), perceived exertion, heart rate (HR).	For running distance, participants ran further in music condition compared to the non-music condition. For arousal, FAS were significantly higher in the music condition compared to the no-music

					condition. For feeling scores, FS is more positive in music condition compared to no-music condition. For perceived exertion, RPE scores in music condition were lower than no-music condition. However for time, RPE scores were higher for 15-30 min than 5-10 min into running in both conditions. For HR, HR for 20-30 min into running was higher than HR for 0-10 min in both conditions.
7.	Lorenzoni, V., De Bie, T., Marchant, T., Van Dyck, E., & Leman, M. (2019). The effect of (a) synchronous music on runners' lower leg impact loading.	28 non-professional runners (15 males), went jogging at least once a month.	Participants were asked to run on their own pace for five sessions with different conditions on 320 m running track which each session lasting for 3 minutes and 30 seconds with the same musical stimulus was played throughout the entire experiment. Participants were given a 5 minutes break after each session to enable sufficient recovery.	Running speed, impact loading, running cadence.	There was no changes for running speed, as participants were requested to keep a constant speed throughout each running session. For impact loading, impact level was higher in music conditions during assessment phase than in the testing phase. For running cadence, it is reported that there is no changes in running cadence in each sessions.
8.	Nikol, L., Kuan, G., Ong, M., Chang, Y. K., & Terry, P. C. (2018). The heat is on: effects of synchronous music	12 healthy male participants who are non smokers and have no respiratory infections, ran at least 3 days per	Participants went through two experimental trials which include running with synchronous music and running without music in	Heart rate (HR), blood lactate, hydration status, rating of perceived exertion (RPE),	Study reported that HR was 1-3 bpm lower at 15 min mark for synchronous music condition compared to the no music condition.

	on psychophysiological parameters and running performance in hot and humid conditions.	week.	climatic chamber. During synchronous music condition, music was played for 60 min while running in the heat chamber at 60% VO_2max and throughout the run to exhaustion at 80% VO_2max.	thermal comfort.	For blood lactate, it is reported that there is no difference between no music and synchronous music condition. For hydration status, it is reported that there is no difference to compare between no music condition and synchronous music condition. For RPE, it is reported that RPE was significantly lower in the synchronous music condition compared to no music condition even though participants completed the same workload. For thermal comfort, it is reported that there is no significant difference to compare both between both conditions.
9.	Ramji, R., Aasa, U., Paulin, J., & Madison, G. (2016). Musical information increases physical performance for synchronous but not asynchronous running.	22 participants (11 male, 11 female) who does non-elite running at least 5km per week, or in regular sports.	Participants ran for two 10-minute trials, with a 20-minute break on a 300 metre track. Participants were not given any instructions on how fast to run or try to synchronize to the music and do what felt natural instead.	Running distance and number of steps, stride length.	Study reported that participants ran faster than the tempo in all asynchronous conditions. For running distance, running distance is further in synchronized music condition compared to asynchronized music condition in music information 3 and 4. For stride length, stride length is longer in synchronized

					music condition compared to asynchronized music condition in music information 3 and 4. Hence, these explains even though participants did not increase their pace, they managed to run further due to an increase in their stride length. HR