SLEEP QUALITY AFTER ACUTE EXERCISE

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INTRODUCTION

The importance of sleep to maintain the physiological functions of the organism and promoting good quality of life is well established in the literature (HANSON and HUECKER, 2021; MEDIC et al., 2017). The opposite is also true, and sleep deprivation is linked to poor health outcomes, such as higher risk of hypertension, diabetes, obesity, depression, anxiety, and mortality (COLTEN and ALTEVOGT, 2006; HANSON and HUECKER, 2021)).

To articulate approaches that support better sleep conditions in the world population, many studies seek to understand the effects of physical exercise on sleep quality. The chronic effect of regular physical activity can decrease sleep onset latency (KING, A C et al., 1997), increase sleep duration (SHARIF et al., 2015) and the prevalence of slow-wave sleep (KING, Abby C. et al., 2008), an indicator of depth of sleep associated with good health (MARTINS et al., 2001).

Besides the physical activity chronic benefits of sleep quality, a single exercise session can bring improvements to the sleep quantity and quality in the same night of the exercise practice (KOVACEVIC et al., 2018; KREDLOW et al., 2015; LARSEN et al., 2019; YOUNGSTEDT et al., 1997). However, some studies shows that acute physical exercise does not always positively modifies sleep variables (MYLLYMÄKI et al., 2011), and its acute effects on sleep quality are still inconclusive.

Those inconsistent findings can be caused by several confounding factors, such as age, sex, level of training, presence, or absence of sleep disorders (YOUNGSTEDT et al., 1997), or even characteristics of the intervention, such as the type of exercise and its intensity (BONARDI et al., 2016; LARSEN et al., 2019; PASSOS et al., 2010; SANTOS et al., 2007). In addition, the main confounding factor could be the running time in relation to bedtime (FLAUSINO et al., 2012; MYLLYMÄKI et al., 2011; SANTOS et al., 2007), since the mediators of sleep quality are physiological mechanisms, such as body temperature (KUMAR, 2004; UCHIDA et al., 2012) and changes in heart rate (MYLLYMÄKI et al., 2012) which vary considerably after and exercise bout.

Thus, the aim of the present study was to identify the acute exercise effects on the different markers of quality and quantity of sleep and the relation to the time it has been performed before the bedtime.

METHODS

A comprehensive search was carried out in the following databases: MEDLINE, Scopus, Embase, Web of Science, Cochrane, CINAHL, SPORT Discus. Below we present the syntax used in the MEDLINE database, through the PubMed interface:("exercise"[mh] OR "physical exertion"[mh] OR "interval training" [tiab] OR aerobic [tiab] OR endurance [tiab] OR strength [tiab] OR jogging[tiab] OR anaerobic[tiab] OR exercise [tiab] OR "high intensity training" [tiab] OR cycling [tiab] OR swim [tiab] OR row [tiab] OR walk [tiab] OR "resistance training" [tiab] OR "physical exertion"[tiab]) AND (sleep [tiab] OR sleep [mh] OR insomnia [tiab] OR "sleep hygiene" [mh] OR "good sleep habits" [tiab] OR polysomnography [mh] OR REM [tiab] OR "rapid eye movement"[tiab]) AND ("controlled clinical trial"[Publication Type] OR "controlled clinical trials as topic"[mh] OR control[tiab] OR "controlled group"[tiab] OR"controlled session"[tiab] OR "control groups"[mh] OR "systematic review" [publication type] OR "meta-analysis"[Publication Type]) AND("nocturnal"[tiab] OR "nighttime" [tiab] OR "daytime"[tiab] OR timing [tiab] OR evening [tiab] OR morning [tiab] OR afternoon [tiab] OR "late-night" [tiab] OR bedtime [tiab] OR "going to bed" [tiab] OR late [tiab] OR "time of day" [tiab] OR "time-of-day" [tiab] OR "daily"[tiab] OR "wake time"[tiab]) NOT ("Review" [Publication Type] OR "Systematic Review" [Publication Type] OR "Meta-Analysis" [Publication Type]) “exercise” OR “physical exertion” AND “sleep” OR sleep hygiene" AND “timing” OR “time of day” AND “controlled clinical trial" OR "control". For the other databases, we used the equivalent terms.

The inclusion criteria were humans with or without disorders of sleep; performing one session of any type of exercise; compared to a group that did not perform exercises; and assessed any sleep quality assessment. Were excluded studies testing chronic exercise interventions, animal studies, review studies (and other studies with non-original data), cross-sectional studies, which were not written in English or Portuguese. Two steps were carried out in the exclusion of studies, the first one was through reading the title and abstract of the studies and the second through the tabulation of information resulting from the full reading of the studies.

Statistical Analysis

The meta-analyses were performed using Comprehensive Meta-Analysis (CMA) software, version 3.3.070. We performed eight principal meta-analyses: Sleep Onset Latency (SOL); Total Sleep Time (TST), Time in Bed (TIB), Wake After Sleep Onset (WASO), REM Stage, Slow Wave Sleep (SWS), Sleep Efficiency (SE), N1 stage and N2 stage; and one variable analysis: Distance between sleep time and bedtime (hours) for the SOL parameter. The effect size was calculated based on standardized mean difference (SMD) for the parameters REM, SWS, WASO, N1 and N2 and for the outcomes presented on the same unit of measure across studies, we used raw mean difference (RMD). When there was significant heterogeneity ($P \leq 0.05$), we calculated the randomized effect and when there was no significant heterogeneity ($P > 0.05$) we used fixed effects. Publication bias was analyzed by the Egger test and a p-value ≤ 0.05 was considered significant.

RESULTS AND DISCUSSION

Initially, 3272 studies were retrieved, and after removing the duplicates, 1742 remained to be screened. In the first exclusion, 767 were excluded by another type of intervention, 274 were excluded for testing the chronic effect of exercise, 396 for not monitoring the parameters of sleep, 120 for being review articles, 45 for performing interventions on animals, 21 for not being original articles and 13 for being written in a foreign language. After this first screening, 96 studies remained. By reading the remaining texts, 13 were excluded for not having a control group, 13 for not being original studies, 10 for testing the chronic effect of exercise, 9 for not evaluating sleep parameters and 5 for not showing any effect independent of exercise. After that, 46 studies were evaluated for eligibility, and 36 were included for analysis.

To carry out the meta-analysis, 3 studies were not included in the main analyzes because they were the only ones with a control group different from the exercised group, yet 1 study was excluded because it did not show the standard deviation of the results.

The results of all meta-analyses were presented in Table 1. Exercise led to a decrease in SOL (RMD= -1.093 minutes, P= 0.031), WASO (SMD= -0.268; p<0.001) and N1 stage (SMD= -0.231; P<0.001); while it led to an increase in TST (RMD= 5.394 minutes; p=0.014), SE (RMD= 1.093 %; P < 0.001). No exercise effects were observed for TIB (RMD=1.140 minutes; p= 0.600), REM Onset

Latency (RMD= 1.348; P= 0.755), REM stage (SMD= -0.052 P= 0.521), SWS (SMD= 0.051, P= 0.592) and N2 stage (SMD= 0.090; P= 0.120).

Table 1. Meta-analyses results.

Time in bed (minutes)									
	RMD	**SE**	**Variance**	**LL**	**UL**	**Z**	**P**	**Sample size**	
Random	-1.140	2.175	4.729	-5.402	3.122	-0.524	0.600	315	
Model	**N**	**Point estimate**	**SE**	**Variance**	**LL**	**UL**		**Z**	**I-squared**
Fixed	26	0.595	1.128	1.273	-1.616	2.807		0.528	52.598
Total sleep time (minutes)									
Random	5.394	2.206	4.866	1.071	9.718	2.445	0.014	607	
Fixed	50	4.021	1.406	1.976	1.266	6.776		2.860	45.942
Sleep onset latency (minutes)									
Random	-1.093	0.507	0.257	-2.087	-0.098	-2.154	0.031	715	
Fixed	58	0.399	0.242	0.059	-0.076	0.873		1.648	51.517
REM Latency (minutes)									
Random	1.348	4.329	18.738	-7.136	9.833	0.312	0.755	292	
Fixed	25	2.999	2.402	5.767	-1.708	7.706		1.249	66.607
Sleep Efficiency (%)									
Random	1.903	0.456	0.208	1.009	2.796	4.173	<0.001	616	
Fixed	52	1.122	0.221	0.049	0.689	1.555		5.083	71.680
REMstage									
Random	-0.052	0.082	0.007	-0.212	0.107	-0.642	0.521	360	
Fixed	31	-0.033	0.055	0.003	-0.141	0.075		-0.598	53.209
Slow wave sleep									
Random	0.051	0.095	0.009	-0.136	0.238	0.537	0.592	203	
Fixed	18	0.033	0.073	0.005	-0.110	0.176		0.452	39.690
Wake after sleep onset									
Random	-0.268	0.077	0.006	-0.419	-0.117	-3.486	<0.001	495	
Fixed	36	-0.245	0.048	0.002	-0.338	-0.151		-5.119	60.470
N1 stage									
Fixed	-0.231	0.059	0.004	-0.348	-0.115	-3.886	<0.001	305	
Fixed	26	-0.231	0.059	0.004	-0.348	-0.115		-3.886	16.003
N2 stage									
Fixed	0.090	0.058	0.003	-0.023	0.203	1.556	0.120	314	
Fixed	27	0.090	0.058	0.003	-0.023	0.203		1.556	0.000

Table 1: RMD= raw mean difference; SMD= standardized mean difference; SE= standard error; N= number of studies; LL= lower limit; UL=upper limit

This review showed that just one exercise session can modify some sleep parameters. However, most of the meta-analyses had high heterogeneity (P<0.05). This inconsistency across studies could be caused by variations in the characteristics of the population and exercise protocols (gender, type and intensity of exercise, level of physical activity of the individuals, time of the exercise session in relation to bedtime, etc.).

Several studies show the relevance of the time interval between exercise practice and bedtime, especially in the interference of Sleep Onset Latency (STUTZ, 2019). Some studies demonstrate that exercise practiced close to bedtime can negatively affect sleep quality (YOUNGSTEADT, 1999). Based on these hypotheses, we performed an analysis using the moderator “distance between exercise and bedtime” in hours, we found that exercise performed ≤2h before bedtime negatively affected sleep onset latency (Table 2); however, when removing the only study that had individuals who had performed the exercise half an hour before bedtime, the result was changed (RMD= 0.624; P= 0.829) and no longer interfered negatively in this sleep parameter. Exercise performed between 2-4h before bedtime brought positive results for SOL (RMD= -2.983; P= 0.010) and when performed ≥4h before bedtime, exercise did not significantly affect SOL (Table 2).

Table 2. Distance between exercise and bedtime (hours) – SOL parameter

	Statistics									
	RMD	LL	UL	Z	P	sample size	Q	df (Q)	P	I-squared
Overall	-1.026	-2.275	-0.010	-1.977	0.048	297	125.928	59.000	0.000	53.148
≤2h	1.820	1.102	2.538	4.969	0.000	92	8.933	7.000	0.258	21.639
2-4h	-2.938	-5.167	-0.709	-2.583	0.010	29	2.334	2.000	0.311	14.306
≥4h	-1.544	-3.327	0.238	-1.698	0.089	176	29.682	16.000	0.020	46.095

Table 2: RMD= raw mean difference; LL= lower limit; UL=upper limit, SOL=Sleep Onset Latency

We did not find enough studies to investigate the physiological mediators involved in sleep alterations. Only 4 studies analyzed heart rate variability, only 1 monitored cortisol secretion after exercise and during sleep, and only 1 monitored plasma melatonin concentration. We know that physical exercise can change the plasma melatonin level, and exercise in the afternoon can decrease this concentration (CARLSON, 2019), however we do not know which sleep parameters plasma melatonin can affect. Yet a review did not confirm that the higher body temperature after exercise practiced in the afternoon could negatively affect sleep quality (STUTZ, 2019).

We still seek to understand how the type of exercise and intensity can alter sleep, since most studies in the literature were carried out with aerobic exercise (mostly running or cycling), and not much is known about resistance exercise effects. Only 4 studies present in this review performed interventions with resistance exercise, and since the different types of exercises could lead t different physiological changes that mediates sleep quality, we would expect different effects from different exercise protocols.

CONCLUSION

Only one session of physical exercise can improve sleep quality, specifically improving Sleep Onset Latency (SOL); Total Sleep Time (TST), and Sleep Efficiency (SE). However, there is high inconsistency across studies and a main confounding factor to understand these effects where the time between the exercise was performed and the time of sleep.

We showed that exercise practiced between 2 and 4h before sleep might be ideal to reduce de sleep onset latency. Furthermore, there is a potential to the exercise performed 2h before going to bed to lead to even poor sleep quality, but it needs to be confirmed in future meta-analysis since we showed it in a heterogeneous meta-analysis, considerably influenced by one study.

At last, the physiological mediators of the exercise benefits remaining to be confirmed and it will be fundamental to prescribe adequate protocols in the future.

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