

Table 3. Study, Participant, and Exercise Characteristics - Acute Exercise Studies																			
Study Characteristics					Participant Characteristics					Exercise Characteristics							Sleep Characteristics		
Author(s)	Year	Subgroup	n <sup>a</sup>	Study design	Population description	M age	% Female	Baseline physical activity level	Identified as having sleep complaints? (y/n)	Intensity	Aerobic or anaerobic	Exercise type	Time of day	Duration (mins/day)	Duration (days/wk)	Total duration (mins)	Assessment type	Objective measure? (y/n)	
Baekeland et al.	1966	Afternoon exercise	10	Open Trial	athletes/regular exercisers	.	0%	high	n	.	aerobic	mixed	.	variable	1	variable	EEG	y	
Baekeland et al.	1966	Evening exercise	(10)	Open Trial	athletes/regular exercisers	.	0%	high	n	.	aerobic	mixed	.	variable	1	variable	EEG	y	
Baekeland et al.	1970		14	Open Trial	athletes/regular exercisers	.	.	high	n	.	mixed	mixed	.	.	1	.	EEG	y	
Zir et al.	1971		5	Open Trial	healthy	20.0	0%	mixed/unknown	n	.	mixed	mixed	mid-day	120	1	120	PSG	y	
Adamson et al.	1974		12	Open Trial	healthy	25.0	0%	mixed/unknown	n	.	aerobic	mixed	morning	variable	1	variable	EEG	y	
Desjardins et al.	1974	High intensity	6	Open Trial	healthy	25.5	0%	mixed/unknown	n	.	aerobic	running	.	120	1	120	.	.	
Desjardins et al.	1974	Low intensity	(6)	Open Trial	healthy	25.5	0%	mixed/unknown	n	.	aerobic	running	.	120	1	120	.	.	
Griffin & Trinder	1978		16	Open Trial	healthy	23.4	50%	mixed/unknown	n	.	aerobic	running	mid-day	variable	1	variable	EEG	y	
Walker et al.	1978	Nonrunners	10	Open Trial	healthy	19.8	0%	mixed/unknown	n	.	aerobic	running	mid-day	13.6	1	13.6	EEG	y	
Walker et al.	1978	Runners	10	Open Trial	athletes/regular exercisers	19.8	0%	high	n	.	aerobic	running	mid-day	35.5	1	35.5	EEG	y	
Browman et al.	1980		7	Open Trial	healthy	20.5	57%	mixed/unknown	n	.	anaerobic	resistance	late night	80	1	80	PSG	y	
Jennings et al.	1981		9	RCT	obese	33.3	100%	mixed/unknown	n	.	vigorous	aerobic	running	.	variable	1	variable	PSG	y
Paxton et al.	1982		24	Open Trial	healthy	21.7	42%	mixed/unknown	n	.	vigorous	aerobic	cycling	mid-day	55	1	55	EEG	y
Trinder et al.	1982		12	Open Trial	athletes/regular exercisers	26.9	17%	high	n	.	mixed	mixed	mid-day	variable	1	variable	EEG	y	
Bunnell et al.	1983a		9	Open Trial	healthy	25.3	56%	mixed/unknown	n	.	moderate	aerobic	walking	morning	151	1	151	EEG	y
Bunnell et al.	1983b	Exercisers	4	Open Trial	athletes/regular exercisers	25.5	50%	high	n	.	aerobic	walking	mid-day	26	1	26	EEG	y	
Bunnell et al.	1983b	Non-Exercisers	4	Open Trial	healthy	25.5	50%	mixed/unknown	n	.	aerobic	walking	mid-day	30	1	30	EEG	y	
Horne et al.	1983	High intensity	8	Open Trial	athletes/regular exercisers	25.4	25%	high	n	.	vigorous	aerobic	running	mid-day	80	1	80	EEG	y
Horne et al.	1983	Low intensity	(8)	Open Trial	athletes/regular exercisers	25.4	25%	high	n	.	light	aerobic	running	mid-day	80	1	80	EEG	y
Paxton et al.	1983		8	Open Trial	athletes/regular exercisers	20.3	0%	high	n	.	mixed	mixed	mid-day	.	1	.	EEG	y	
Matsumoto et al.	1984		6	Open Trial	healthy	22.0	0%	mixed/unknown	n	.	moderate	aerobic	cycling	.	140	1	140	PSG	y
Horne & Moore	1985		6	Open Trial	athletes/regular exercisers	21.5	100%	high	n	.	vigorous	aerobic	running	mid-day	80	1	80	EEG	y
Kupfer et al.	1985	Double exercise	10	Open Trial	athletes/regular exercisers	24.8	0%	high	n	.	aerobic	running	.	variable	1	variable	EEG	y	
Kupfer et al.	1985	Regular exercise	(10)	Open Trial	athletes/regular exercisers	24.8	0%	high	n	.	aerobic	running	.	variable	1	variable	EEG	y	
Montgomery et al	1985		8	Open Trial	athletes/regular exercisers	40.8	.	high	n	.	aerobic	running	mid-day	90	1	90	.	.	
Shapiro et al.	1985	Neutral environment	4	Open Trial	healthy	19.8	0%	mixed/unknown	n	.	aerobic	running	morning	12	1	12	PSG	y	
Driver et al.	1988		9	Open Trial	healthy	24.0	100%	low	n	.	vigorous	aerobic	cycling	mid-day	60	1	60	EEG	y
Montgomery et al	1988	Experiment 1	7	Open Trial	athletes/regular exercisers	23	0%	high	n	.	aerobic	.	.	.	1	.	EEG	y	
Montgomery et al	1988	Experiment 2	22	Open Trial	athletes/regular exercisers	32.5	0%	high	n	.	aerobic	.	.	.	1	.	EEG	y	
Montgomery et al	1988	Experiment 3	10	Open Trial	athletes/regular exercisers	22.5	.	high	n	.	anaerobic	power training	.	.	1	.	EEG	y	
Vein et al.	1991		30	Open Trial	healthy	27.0	0%	mixed/unknown	n	.	aerobic	cycling	late night	120	1	120	PSG	y	
Bevier et al.	1992		14	Open Trial	healthy	63.9	57%	mixed/unknown	n	.	moderate	aerobic	walking	mid-day	60	1	60	EEG	y
Driver et al.	1994		8	Open Trial	athletes/regular exercisers	30.0	0%	high	n	.	aerobic	running	morning	65	1	65	EEG	y	
Montmayer et al.	1994		4	Open Trial	athletes/regular exercisers	23.0	0%	high	n	.	aerobic	cycling	mid-day	66	1	66	PSG	y	
O'Connor et al.	1998	Low intensity	8	Open Trial	healthy	20.8	0%	mixed/unknown	n	.	aerobic	cycling	late night	60	1	60	SAD	n	
O'Connor et al.	1998	Moderate intensity	(8)	Open Trial	healthy	20.8	0%	mixed/unknown	n	.	moderate	aerobic	cycling	late night	60	1	60	SAD	n
Oda et al.	2001		8	Open Trial	healthy	22.8	0%	mixed/unknown	n	.	light	aerobic	underwater aerobics	mid-day	50	1	50	PSG	y
Hague et al.	2003		15	Open Trial	athletes/regular exercisers	21.7	50%	high	n	.	aerobic	mixed	.	129	1	129	ACT	y	
Alessi et al.	2005		118	RCT	nursing home residents	86.9	77%	mixed/unknown	n	.	mixed	mixed	.	45	5	225	ACT	y	
Esteves et al.	2009		22	Open Trial	PLM patients	46.3	64%	low	y	.	vigorous	aerobic	cycling	morning	variable	1	variable	PSG	y
Passos et al.	2010	High aerobic	24	RCT	insomnia patients	43.7	75%	mixed/unknown	y	.	vigorous	aerobic	running	mid-day	30	1	30	PSG	y
Passos et al.	2010	Moderate aerobic	12(12)	RCT	insomnia patients	46.5	79%	mixed/unknown	y	.	moderate	aerobic	running	mid-day	50	1	50	PSG	y
Passos et al.	2010	Moderate resistance	12(12)	RCT	insomnia patients	43.8	79%	mixed/unknown	y	.	moderate	anaerobic	mixed	mid-day	50	1	50	PSG	y
Bulckaert et al.	2011		9	Open Trial	healthy	23.0	56%	mixed/unknown	n	.	moderate	aerobic	cycling	late night	60	1	60	PSG	y
Morita et al.	2011		42	Open Trial	sleep complaints	44.4	39%	mixed/unknown	y	.	aerobic	walking	morning	120	1	120	SR/ACT	mixed	
Myllymäki et al.	2011		11	Open Trial	healthy	26.0	36%	mixed/unknown	n	.	vigorous	aerobic	cycling	late night	35	1	35	PSG/ACT	y
Flausino et al.	2012	30 mins, VT1	17	Open Trial	healthy	27.2	0%	mixed/unknown	n	.	moderate	aerobic	running	late night	30	1	30	PSG	y
Flausino et al.	2012	60 mins, VT1	(17)	Open Trial	healthy	27.2	0%	mixed/unknown	n	.	aerobic	running	late night	60	1	60	PSG	y	
Flausino et al.	2012	30 mins, VT1.5	(17)	Open Trial	healthy	27.2	0%	mixed/unknown	n	.	vigorous	aerobic	running	late night	30	1	30	PSG	y
Flausino et al.	2012	60 mins, VT1.5	(17)	Open Trial	healthy	27.2	0%	mixed/unknown	n	.	aerobic	running	late night	60	1	60	PSG	y	
Myllymäki et al.	2012	30 mins, easy	14	Open Trial	healthy	35.9	0%	mixed/unknown	n	.	light	aerobic	running	mid-day	30	1	30	ACT	y
Myllymäki et al.	2012	30 mins, moderate	(14)	Open Trial	healthy	35.9	0%	mixed/unknown	n	.	moderate	aerobic	running	mid-day	30	1	30	ACT	y
Myllymäki et al.	2012	30 mins, vigorous	(14)	Open Trial	healthy	35.9	0%	mixed/unknown	n	.	vigorous	aerobic	running	mid-day	30	1	30	ACT	y
Myllymäki et al.	2012	60 mins, moderate	(14)	Open Trial	healthy	35.9	0%	mixed/unknown	n	.	moderate	aerobic	running	mid-day	60	1	60	ACT	y
Myllymäki et al.	2012	90 mins, moderate	(14)	Open Trial	healthy	35.9	0%	mixed/unknown	n	.	moderate	aerobic	running	mid-day	90	1	90	ACT	y
Viana et al.	2012		40	RCT	healthy	68.0	0%	low	n	.	moderate	anaerobic	resistance	morning	55	1	55	PSG	y
Wong et al.	2013	45% VO2max	12	Open Trial	healthy	25.2	75%	low	n	.	light	aerobic	running	mid-day	46	1	46	PSG	y
Wong et al.	2013	55% VO2max	(12)	Open Trial	healthy	25.2	75%	low	n	.	moderate	aerobic	running	mid-day	46	1	46	PSG	y
Wong et al.	2013	65% VO2max	(12)	Open Trial	healthy	25.2	75%	low	n	.	vigorous	aerobic	running	mid-day	46	1	46	PSG	y
Wong et al.	2013	75% VO2max	(12)	Open Trial	healthy	25.2	75%	low	n	.	vigorous	aerobic	running	mid-day	46	1	46	PSG	y

<sup>a</sup>Participants utilized multiple times are noted in parentheses

Definitions and abbreviations are listed below

ACT = Actigraphy, EEG = Electroencephalogram, PLM = Periodic Leg Movement, PSG = Polysomnography, RC = Randomized Controlled Trial, SAD = Sleep Assessment Device, SR = Self Report, % VO2max = Percent of Maximal Oxygen Uptake, VT= Ventilatory Threshold

The Effects of Physical Activity on Sleep: A Meta-Analytic Review

Journal of Behavioral Medicine

M. Alexandra Kredlow, Michelle C. Capozzoli, Bridget A. Heaton, Amanda W. Calkins, and Michael W. Otto

Boston University

kredlow@bu.edu

Author(s)	Year	Study Characteristics			Participant Characteristics				Exercise Characteristics								Sleep Characteristics				
		Subgroup	n <sup>a</sup>	Study design	Population description	Male	% Female	Baseline physical activity level	Identified as having sleep complaints? (y/n)	Intensity	Aerobic or anaerobic	Exercise type	Mind body exercise? (y/n)	Time of day	Duration (mins/day)	Duration (days/wk)	Durations (wks)	Total duration (mins)	Adherence	Assessment type	Objective measure? (y/n)
Jennings et al.	1981		9	RCT	obese	33.3	100%	mixed/unknown	n	vigorous	mixed	mixed	n	mid-day	60	3	9	1620	107.0%	PSG	y
Guilleminault et al.	1995		20	RCT	insomnia patients	44.0	56%	mixed/unknown	y	vigorous	aerobic	walking	n	mid-day	45	7	4	1260		ACT	y
King et al.	1997		43	RCT	sleep complaints	61.4	67%	low	y	vigorous	aerobic	mixed	n	mid-day	50	4	16	3200	93.6%	PSQI/SR	n
Alessi et al.	1999		29	RCT	nursing home residents	88.5	90%	mixed/unknown	n		mixed	mixed	n	morning/mid-day	58.4	5	14	4088	83.7%	ACT	y
Naylor et al.	2000		23	Matched CT	nursing home residents	75.6	65%	mixed/unknown	n		mixed	mixed	n	morning/evening	45	7	2	630		EEG	y
King et al.	2002		85	RCT	caregivers	62.7	100%	low	n	moderate	mixed	mixed	n		35	4	52	7280	73.4%	PSQI	n
Tworoger et al.	2003		173	RCT	overweight/obese postmenopausal	60.7	100%	low	n	moderate	aerobic	mixed	n	variable	45	5	52	11700		WHIR	n
de Jong et al.	2006		181	RCT	healthy	59.1	56%	low	n		mixed	mixed	n	variable	60	1	15	900	80.0%	TAAQOL	n
Elavsky et al.	2007	Walking	102	RCT	healthy	49.9	100%	low	n	vigorous	aerobic	walking	n		60	3	16	2880	70.0%	PSQI	n
Elavsky et al.	2007	Yoga	61(39)	RCT	healthy	49.9	100%	low	n		anaerobic	yoga	y		90	2	16	2880	63.0%	PSQI	n
Frye et al.	2007	Low impact exercise	49	RCT	healthy	69.2	64%	low	n		mixed	mixed	n	variable	60	3	12	2160	91.4%	PSQI	n
Frye et al.	2007	Tai Chi	23(21)	RCT	healthy	69.2	64%	low	n		mixed	tai chi	y	variable	60	3	12	2160	91.4%	PSQI	n
Littman et al.	2007		167	RCT	healthy	61.0	100%	low	n	moderate	aerobic	mixed	n		45	5	52	11700		WHIR	n
King et al.	2008		66	RCT	sleep complaints	61.4	67%	low	y	moderate	mixed	mixed	n	morning/mid-day	42	5	52	10920	74.0%	PSQI/PSG	mixed
Chen et al.	2009		128	RCT	healthy	69.2	73%	mixed/unknown	n		mixed	yoga	y		70	3	24	5040	87.0%	PSQI	n
Manzanogue et al.	2009		39	RCT	healthy	19.5	87%	mixed/unknown	n		mixed	gigong	y		30	3	4	360		PSQI	n
Chen et al.	2010		55	RCT	nursing home residents	75.4	53%	mixed/unknown	n		mixed	yoga	y		70	3	24	5040	80.8%	PSQI	n
Reid et al.	2010		17	RCT	insomnia patients	61.6	94%	low	y	moderate	aerobic	mixed	n	mid-day	40	4	16	2560		PSQI/SR	n
Hosseini et al.	2011		56	RCT	nursing home residents	69.1	52%	mixed/unknown	n		mixed	tai chi	y		25	3	12	900		PSQI	n
Richards et al.	2011		102	RCT	nursing home residents	82.0	64%	mixed/unknown	n		anaerobic	mixed	n	mid-day	28	5	7	980	80.0%	PSG	y
Chen et al.	2012		55	RCT	healthy	71.8	66%	mixed/unknown	n		mixed	gigong	y		30	3	12	1080		PSQI	n
Kalak et al.	2012		51	RCT	healthy	18.3	53%	mixed/unknown	n		aerobic	running	n	morning	33.5	5	3	502.5		ISI/EEG	mixed
Kline et al.	2012	4 KKW	243	RCT	healthy	57.3	100%	low	n	moderate	aerobic	mixed	n		variable	3.5	24		95.1%	SPI	n
Kline et al.	2012	8 KKW	99(92)	RCT	healthy	57.3	100%	low	n	moderate	aerobic	mixed	n		variable	3.5	24		88.5%	SPI	n
Kline et al.	2012	12 KKW	95(92)	RCT	healthy	57.3	100%	low	n	moderate	aerobic	mixed	n		variable	3.5	24		92.5%	SPI	n
Nguyen et al.	2012		73	RCT	healthy	69.0	50%	mixed/unknown	n		mixed	tai chi	y		60	2	24	2880		PSQI	n
Yeh et al.	2012		70	Matched CT	healthy	48.6	100%	mixed/unknown	n		anaerobic	gigong	y		30	7	12	2520		PSQI	n
Oudegeest-Sander et al.	2013		21	RCT	healthy	69.0	48%	low	n	vigorous	aerobic	cycling	n		45	3	52	7020	91.0%	ACC	y
Pinniger et al.	2013	Exercise	35	RCT	depression/anxiety symptoms	39.5	89%	mixed/unknown	n		mixed	mixed	n		90	1	8	720	77.0%	ISI	n
Pinniger et al.	2013	Tango	23(18)	RCT	depression/anxiety symptoms	39.5	90%	mixed/unknown	n		mixed	tango	n		90	1	8	720	77.0%	ISI	n

<sup>a</sup>Participants utilized multiple times are noted in parentheses  
Definitions and abbreviations are listed below

ACC = Accelerometer, ACT = Actigraphy, EEG = Electroencephalogram, ISI = Insomnia Severity Index, Matched CT = Matched Controlled Trial, PLM = Periodic Leg Movement, PSG = Polysomnography, PSQI = Pittsburg Sleep Quality Inventory, RCT = Randomized Controlled Trial, SAD = Sleep Assessment Device, SR = Self Report, TAAQOL = TNO-AZL Adult Quality of Life, SPI = Sleep Problems Index, %VO2max = Percent of Maximal Oxygen Uptake, VT= Ventilatory Threshold, WHIRS = Women's Health Initiative Insomnia Rating Scale

The Effects of Physical Activity on Sleep: A Meta-Analytic Review

Journal of Behavioral Medicine

M. Alexandra Kredlow, Michelle C. Capozzoli, Bridget A. Hearon, Amanda W. Calkins, and Michael W. Otto

Boston University

[kredlow@bu.edu](mailto:kredlow@bu.edu)