Principles and Practice of Clinical Research
A Global Journal in Clinical Research
PPCR
ISSN: 2378-1890

Exercise-induced pain threshold modulation in healthy subjects: a systematic review and meta-analysis.

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Received August 10, 2020; accepted September 14, 2020; published September 16, 2020.

APPENDICES

Appendix A: PRISMA Checklist.

Section/Topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	01
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	02
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	04
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	04
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	05

Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	05
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	05
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	05-06
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	05-06
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	05-06
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	05-06
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	06
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	06
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	NA
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	NA
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	07
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	07
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	08
Results of	20	For all outcomes considered (benefits or harms), present,	

individual studies		for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	08
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	08
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	NA
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	09
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of	09-10
		identified research, reporting bias).	
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	12
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	01

Reference: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097.

Appendix B: Search strategy.

Database	Date	Terms
MEDLINE PubMed	12/2/2019	("exercise"[MeSH Terms] OR "Exercise therapy"[Mesh Terms] OR "Exercise Movement Techniques"[Mesh Terms] OR "exercise"[Title/Abstract] OR "physical activity"[Title/Abstract]) AND ("exercise induced hypoalgesia"[Title/Abstract] OR "EIH"[Title/Abstract] OR "Conditioning pain modulation"[Title/Abstract] OR "conditioned pain modulation"[Title/Abstract] OR "dnic"[Title/Abstract] OR "diffuse noxious inhibitory control"[MESH Terms] OR "diffuse noxious inhibitory control"[Title/Abstract] OR "temporal summation"[Title/Abstract] OR "qst"[Title/Abstract] OR "quantitative sensory testing"[Title/Abstract] OR "exercise induced analgesia"[Title/Abstract] OR "pain threshold"[Mesh Terms] OR "pain threshold"[Title/Abstract])
LILACS	12/2/2019	(tw:("physical activity")) OR (tw:(exercise)) OR (tw:(kinesiotherapy)) AND (tw:("Exercise-induced hypoalgesia")) OR (tw:("Exercise-induced analgesia")) OR (tw:("Temporal Summation")) OR (tw:(DNIC)) OR (tw:("Conditioned Pain Modulation")) OR (tw:("Diffuse Noxious Inhibitory Control")) OR (tw:("pain threshold")) OR (tw:("quantitative sensory testing"))
EMBASE	12/2/2019	('exercise'/exp OR 'exercise':ab,ti OR 'physical activity'/exp OR 'physical activity':ab,ti OR 'kinesiotherapy':ab,ti OR 'kinesiotherapy'/exp) AND ('diffuse noxious inhibitory control'/exp OR 'diffuse noxious inhibitory control':ab,ti OR 'temporal summation'/exp OR 'temporal summation':ab,ti OR 'pain threshold'/exp OR 'pain threshold':ab,ti OR 'dnic':ab,ti OR 'quantitative sensory testing':ab,ti OR 'qst':ab,ti OR 'eih':ab,ti OR 'exercise induced hypoalgesia':ab,ti OR 'exercise induced analgesia':ab,ti OR 'conditioning pain modulation':ab,ti OR 'conditioned pain modulation':ab,ti) NOT ([medline]/lim OR [pubmed-not-medline]/lim)
Web of Science	12/2/2019	(TS=(exercise induced hypoalgesia) OR TS=(pain threshold) OR TS=(Conditioning pain modulation) OR TS=(conditioned pain modulation) OR TS=(eih) OR TS=(dnic) OR TS=(diffuse noxious inhibitory control) OR TS=(temporal summation) OR TS=(qst) OR TS=(quantitative sensory testing) OR TS=(exercise induced analgesia) OR TS=(pain threshold)) AND (TS=(Exercise)

		OR TS=(Exercise therapy) OR TS=(Exercise Movement Techniques) OR TS=(Resistance training) OR TS=(aerobic exercise) OR TS=(kinesiotherapy))
Scopus	12/2/2019	TITLE-ABS-KEY ("Exercise" OR "Exercise therapy" OR "Exercise Movement Techniques" OR "Resistance training" OR "aerobic exercise" OR "kinesiotherapy") AND TITLE-ABS-KEY ("Exercise" OR "Exercise therapy" OR "Exercise Movement Techniques" OR "Resistance training" OR "aerobic exercise" OR "kinesiotherapy") AND TITLE-ABS-KEY ("exercise induced hypoalgesia" OR "EIH" OR "Conditioning pain modulation" OR "conditioned pain modulation" OR "dnic" OR "diffuse noxious inhibitory control" OR "diffuse noxious inhibitory control" OR "temporal summation" OR "qst" OR "quantitative sensory testing" OR "exercise induced analgesia" OR "pain threshold" OR "pain threshold")
Pedro	12/2/2019	("exercise" OR "Exercise therapy" OR "Exercise Movement Techniques" OR "exercise" OR "physical activity") AND ("exercise induced hypoalgesia" OR "EIH" "Conditioning pain modulation" OR "conditioned pain modulation"

Appendix C: Studies that were evaluated in full-text and were excluded.

N	Author	Year	Title	Reason for exclusion
1	Tarr, B. et al	2015	Synchrony and exertion during dance independently raise pain threshold and encourage social bonding.	Protocol
2	Slater, H., L. ET AL	2005	Sensory and motor effects of experimental muscle pain in patients with lateral epicondylalgia and controls with delayed onset muscle soreness.	Protocol
3	Sluka, K. A. ET AL	2018	Exercise-induced pain and analgesia? Underlying mechanisms and clinical translation.	Review article
4	Smith, A. and A. Pedler	2018	Conditioned pain modulation is affected by occlusion cuff conditioning stimulus intensity, but not duration.	Protocol
5	Sternberg, W. F. ET AL	2001	Sex-dependent components of the analgesia produced by athletic competition.	Protocol
6	Sullivan, P., M. Gagnon, K. Gammage and S. Peters	2015	Is the effect of behavioral synchrony on cooperative behavior mediated by pain threshold.	The data was not extractable

7	Szucs, K., A. et al.	2016	Dosing exercise to treat pain: a randomized human trial.	Conference abstract
8	Tampin, B., J. Vollert and A. B. Schmid	2018	Sensory profiles are comparable in patients with distal and proximal entrapment neuropathies, while the pain experience differs.	Protocol
9	Thomas, S.et al.	2019	The effects of acute exercise on thermal sensory function.	Conference abstract
10	Torgen, M. and C. Swerup	2002	Individual factors and physical workload in relation to sensory thresholds in a middle-aged general population sample.	Protocol
11	Torisu, T., K. et al	2010	Effects of eccentric jaw exercise on temporal summation in jaw-closing muscles of healthy subjects.	Protocol
12	Tronarp, R.et al	2018	Office-cycling: a promising way to raise pain thresholds and increase metabolism with minimal compromising of work performance.	The data was not extractable
13	Tsauo, J. Y	2004	Physical exercise and health education for neck and shoulder complaints among sedentary workers.	Protocol
14	Tynes, B. K.	2013	The effect of exercise on pressure pain threshold in the presence and absence of doms.	Conference abstract
15	Umbel, J. D	2009	Delayed-onset muscle soreness induced by low-load blood flow-restricted exercise.	Protocol
16	Umeda M.	2019	Comparisons of conditioned pain modulation and physical activity between hispanic and non-hispanic white adults.	Protocol
17	Umeda M.	2017	Conditioned pain modulation among young, healthy, and physically active african american and non-hispanic white adults.	Protocol
18	Umeda M.	2016	A smaller magnitude of exercise-induced hypoalgesia in african americans compared to non-hispanic whites: a potential influence of physical activity.	Protocol
19	Umeda M.	2016	Influence of moderate intensity physical activity levels and gender on conditioned pain modulation.	Protocol
20	Umeda M.	2010	Examination of the dose-response relationship between pain perception and blood pressure elevations induced by isometric exercise in men and women.	Protocol
21	Umeda M.	2009	Influence of blood pressure elevations by isometric exercise on pain perception in women.	Protocol
22	Umeda M.	2015	Muscle pain and blood pressure responses during isometric handgrip exercise in healthy african american and non-hispanic white adults.	Protocol
23	Vaegter, H. B.	2019	Hypoalgesia after bicycling at lactate threshold is reliable between sessions.	The data could not be compared
24	Vaegter, H. B.	2018	Test-retest reliabilty of exercise-induced hypoalgesia after aerobic exercise.	The data could not be compared

25	Vaegter, H. B.	2014	Similarities between exercise-induced hypoalgesia and conditioned pain modulation in humans.	The data could not be compared
26	Vaegter, H. B.	2015	Isometric exercises reduce temporal summation of pressure pain in humans.	The data could not be compared
27	Vaegter, H. B.	2018	Assessment of cpm reliability: quantification of the within-subject reliability of 10 different protocols.	Protocol
28	Valenza, A.	2019	Thermosensory mapping of skin wetness sensitivity across the body of young males and females at rest and following maximal incremental running.	Protocol
29	Valenza, M.	2016	Acute effects of contract-relax stretching vs. Tens in young subjects with anterior knee pain: a randomized controlled trial.	Protocol
30	Verbrugghe, J.	2017	Skill training preferences and technology use in persons with neck and low back pain.	Protocol
31	Villemure, C	2014	Insular cortex mediates increased pain tolerance in yoga practitioners.	Protocol
32	Waite, S.	2017	Evaluation of factors influencing the relationship between physical activity, the perception of pain and psychological attitudes to pain in humans.	Review article
33	Wright, A.	2017	Cold pain threshold identifies a subgroup of individuals with knee osteoarthritis that present with multimodality hyperalgesia and elevated pain levels.	The data could not be compared
34	Yoon, S.	2019	Effects of cycling while typing on upper limb and performance characteristics.	Protocol
35	Zeller, L.	2011	The effect of exercise cessation on non-articular tenderness measures and quality of life in well-trained athletes.	Protocol
36	Zeller, L.	2019	Pain sensitivity and athletic performance.	Protocol
37	S. Papalia, D. De Plater	2011	Does a bout of DOMS improve physical performance?	Conference abstract
38	G. Sari, S. Kanyılmaz	2014	Efficacy of transcutaneous electrical stimulation (tens) and kinesiotaping in patients with lateral epicondylitis.	Conference abstract
39	Wenchun Qu	2011	The associations between extension muscle strength and pressure pain threshold in fibromyalgia.	Conference abstract
40	Nilima Shankar	2013	Effect of stress and yogic relaxation techniques (anulomvilom & shavasana) on cold induced pain perception in medical undergraduate students.	Protocol
41	William A. Sands	2008	Effect of vibration on forward split flexibility and pain perception in young male gymnasts.	Protocol
42	Michael S. Rathleff	2016	Self-reported recovery is associated with improvement in localized hyperalgesia among adolescent females with patellofemoral pain.	Protocol
43	Pernille Kofoed Nielsen	2010	Effect of physical training on pain sensitivity and trapezius muscle morphology.	Protocol
44	Ebonie Rio	2015	Isometric exercise induces analgesia and reduces inhibition in patellar tendinopathy.	Protocol

45	Lígia Inez Silva	2013	Evaluation of the pressure pain threshold after neural mobilization in individuals with sciatica.	Protocol
46	Luis Peñailillo	2018	Effects of eccentric cycling performed at long vs. Short muscle lengths on heart rate, rate perceived effort, and muscle damage markers.	Protocol
47	William A. Sands	2015	Dynamic compression enhances pressure-to- pain threshold in elite athlete recovery: exploratory study.	Protocol
48	Pokhrel BR	2013	Effect of sub-maximal exercise stress on cold pressor pain: a gender based study.	Protocol
49	Mehmet Akif Serinken	2013	The effect of eccentric exercise-induced delayed-onset muscle soreness on positioning sense and shooting percentage in wheelchair basketball players.	Protocol
50	Pertovaara, etal	1984	The influence of exercise on dental pain thresholds and the release of stress hormones.	Protocol
51	Benjamin Pageaux	2015	Central alterations of neuromuscular function and feedback from group iii-iv muscle afferents following exhaustive high-intensity one-leg dynamic exercise.	Protocol
52	Thomas J. O'Leary	2017	High but not moderate-intensity endurance training increases pain tolerance: a randomized trial.	Protocol
53	Patrick J. O'Connor	2001	Moderate-intensity muscle pain can be produced and sustained during cycle ergometry.	Protocol
54	Olav Olsen	2012	The effect of warm-up and cool-down exercise on delayed onset muscle soreness in the quadriceps muscle: a randomized controlled trial.	Protocol
55	Shannon M. Petersen	2019	Self-reported sinus headaches are associated with neck pain and cervical musculoskeletal dysfunction: a preliminary observational case control study.	Protocol
56	Yukiko Shiro	2017	Physical activity may be associated with conditioned pain modulation in women but not men among healthy individuals.	Protocol
57	Pekka Paalasmaa,	1991	Modulation of skin sensitivity by dynamic and isometric exercise in man.	Protocol
58	Tomasz Sipko	2018	Effect of sacroiliac joint mobilization on the level of soft tissue pain threshold in asymptomatic women.	Protocol
59	Sencan, S.	2004	A study to compare the therapeutic efficacy of aerobic exercise and paroxetine in fibromyalgia syndrome.	Protocol
60	Ristic, D.	2015	Aerobic exercise reduces pallesthesia and myofascial pain in man.	Conference abstract
61	Pinto, J.	2018	Cold-water immersion has no effect on muscle stiffness after exercise-induced muscle damage.	Protocol
62	Peñailillo, L.	2017	Metabolic demand and muscle damage induced by eccentric cycling of knee extensor and flexor muscles.	Protocol
63	Ruble, S. B	2005	Thermal pain perception after aerobic exercise.	Protocol
64	Sands, W. A	2015	Dynamic compression enhances pressure-to-pain threshold in elite athlete recovery: exploratory study.	Protocol
65	Calvo-lobo et al	2017	Tensiomyography, sonoelastography, and mechanosensitivity differences between active, latent, and	Protocol

			control low back myofascial trigger points: a cross-sectional study	
66	Carey et al	2017	Active gaming as a form of exercise to induce hypoalgesia.	Protocol
67	Choi et al	2017	The strengthening effect of electrical stimulation on lumbar paraspinal muscles in the sitting position: a randomized controlled trial.	Protocol
68	Alaca et al	2015	The relationship between internet addiction and physical activity, depression and latent trigger point algometer scores in university students.	Conference abstract
69	Alsouhibain et al	2016	Exercise-induced hypoalgesia following six minute walk test.	Conference abstract
70	Andersen et al	2010	Increased trapezius pain sensitivity is not associated with increased tissue hardness.	Protocol
71	Attridge et al	2016	The effect of pain on task switching: pain reduces accuracy and increases reaction times across multiple switching paradigms.	Protocol
72	Awali et al	2017	Differences in temporal summation using heat and mechanical noxious stimuli.	Conference abstract
73	Awali et al	2017	Differences in temporal summation using heat and mechanical noxious stimuli.	Conference abstract
74	Babel	2016	Memory of pain induced by physical exercise.	Protocol
75	Bishop et al	2011	Immediate reduction in temporal sensory summation after thoracic spinal manipulation.	The data could not be extracted
76	Bisset et al	2008	Unilateral lateral epicondylalgia shows a pro-nociceptive pain profile: a case-control observational study.	Protocol
77	Brellenthin et al	2012	The influence of submaximal isometric exercise on temporal summation of heat pain.	Conference abstract
78	Bartholdi et al	2015	Local and systemic changes in pain sensitivity after 4 weeks of calf muscle stretching in a nonpainful population: a randomized trial.	Protocol
79	Ayles et al	2011	Vibration-induced afferent activity augments delayed onset muscle allodynia.	Protocol
80	Aweid et al	2013	Medial tibial pain pressure threshold algometry in runners.	Protocol
81	Bement et al	2008	Dose response of isometric contractions on pain perception in healthy adults.	Protocol
82	Anshel et al	1994	Effect of aerobic and strength training on pain tolerance, pain appraisal and mood of unfit males as a function of pain location.	The data could not be compared
83	Binderup et al	2010	Pressure pain threshold mapping of the trapezius muscle reveals heterogeneity in the distribution of muscular hyperalgesia after eccentric exercise.	Protocol
84	Baiamont et al	2017	Exercise-induced hypoalgesia: pain tolerance, preference and tolerance for exercise intensity, and physiological correlates following dynamic circuit resistance exercise.	The data could not be compared

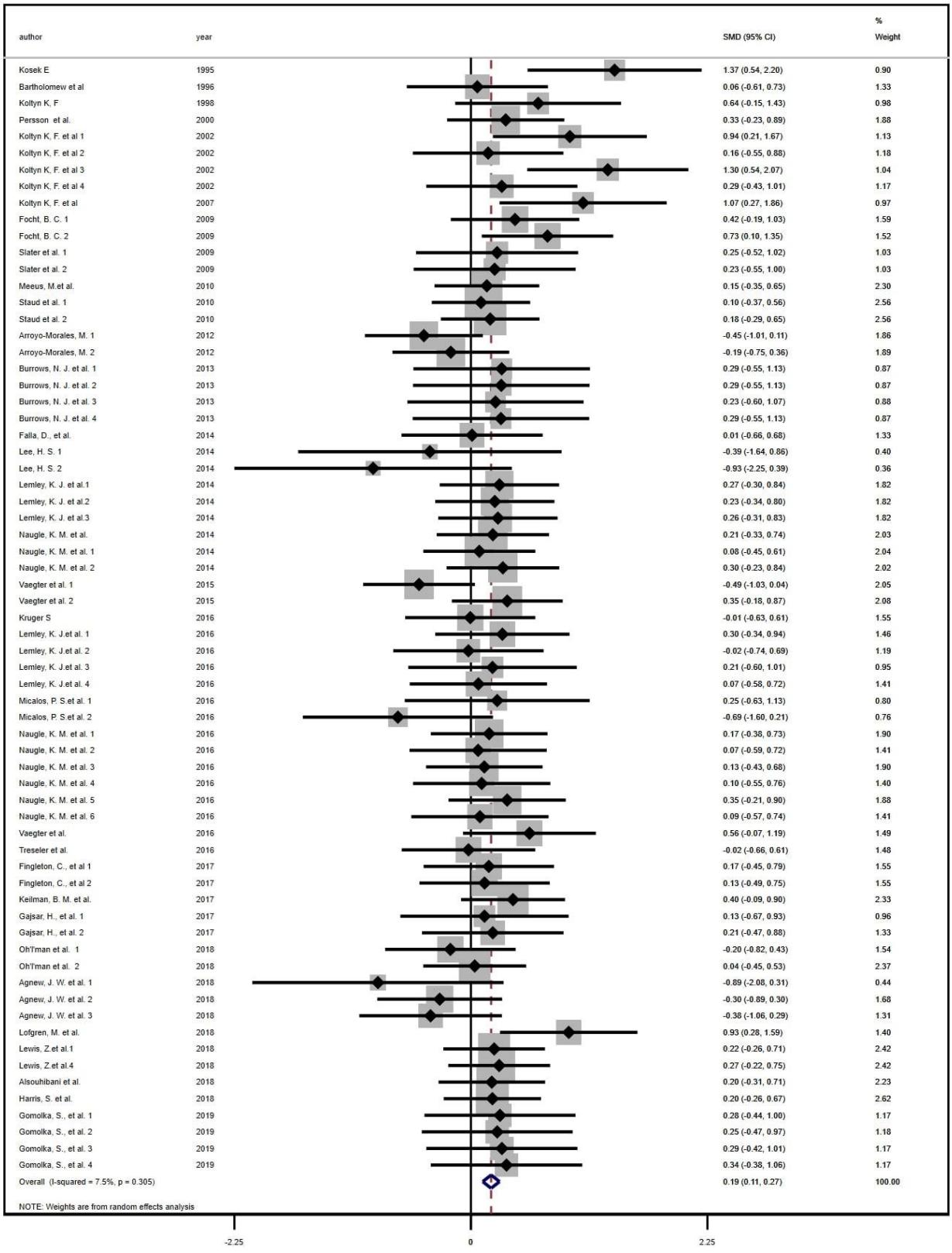
85	Black et al	2016	Local and generalized endogenous pain modulation in healthy men: effects of exercise and exercise-induced muscle damage.	Protocol
86	Bucci et al	2018	Two repetitive bouts of intense eccentric-concentric jaw exercises reduce experimental muscle pain in healthy subjects.	Protocol
87	Naugle, K. et al.	2015	Dysfunction of endogenous pain inhibition following acute aerobic exercise in healthy older adults.	Conference abstract
88	Naugle, K. et al.	2016	Light physical activity behavior predicts pain modulatory function in healthy older adults.	Conference abstract
89	Alaca, N. et al.	2015	The relationships between internet addiction and physical activity, depression and latent trigger point algometer scores in university students.	Conference abstract
90	Alsouhibani, A. et al.	2016	Exercise-induced hypoalgesia following six minute walk test.	Conference abstract
91	Awali, A. et al.	2017	Differences in temporal summation using heat and mechanical noxious stimuli.	Conference abstract
92	Bajaj, P. et al.	2000	Muscle hyperalgesia in postexercise muscle soreness assessed by single and repetitive ultrasound stimuli.	Protocol
93	Bakhtiary, A. H. et al.	2007	Influence of vibration on delayed onset of muscle soreness following eccentric exercise.	Protocol
94	Barlas, P. et al.	2000	Delayed onset muscle soreness: effect of an ischaemic block upon mechanical allodynia in humans.	Protocol
95	Bement, M. H.	2014	Men report greater pain relief following sustained static contractions than women when matched for baseline pain.	Protocol
96	Bement, M. K. H.	2009	The role of the menstrual cycle phase in pain perception before and after an isometric fatiguing contraction.	Protocol
97	Binderup, A. T.	2009	Studying changes in pressure pain topography of the trapezius muscle.	Conference abstract
98	Brellenthin, A. G. et al.	2017	Psychosocial influences on exercise-induced hypoalgesia.	Protocol
99	Caravalho, A. et al.	2013	Delayed hypoalgesia to a heat stimulus is induced by eccentric exercise and is greater for red-than dark-haired women.	Protocol
100	Cheatham, S. W. et al.	2019	Does a light pressure instrument assisted soft tissue mobilization technique modulate tactile discrimination and perceived pain in healthy individuals with DOMS?	Protocol
101	Burrows, N. J. et al.	2014	Acute resistance exercise and pressure pain sensitivity in knee osteoarthritis: a randomised crossover trial.	Protocol
102	Cheung, J. et al.	2013	The relationship between neck pain and physical activity.	Protocol
103	Choi, S. H. et al.	2013	The effects of stability exercises on shoulder pain and function of middle-aged women.	Protocol
104	Hennings, A. et al.	2012	The influence of physical activity on pain thresholds in patients with depression and multiple somatoform symptoms.	Protocol
105	Henriksen, M.	2013	Exercise therapy reduces pain sensitivity in patients with knee osteoarthritis: a randomized controlled trial.	Protocol

106	Henriksen, M. et al.	2014	Association of exercise therapy and reduction of pain sensitivity in patients with knee osteoarthritis: a randomized controlled trial.	Protocol
107	Jakobsen, M. D. et al.	2018	Effect of physical exercise on musculoskeletal pain in multiple body regions among healthcare workers: secondary analysis of a cluster randomized controlled trial.	Protocol
108	Jones, D. H. et al.	2007	Test-retest reliability of pressure pain threshold measurements of the upper limb and torso in young healthy women.	Protocol
109	Jones, M. D. et al.	2017	Occlusion of blood flow attenuates exercise-induced hypoalgesia in the occluded limb of healthy adults.	Protocol
110	Jonhagen, S. et al.	2009	Forward lunge: a training study of eccentric exercises of the lower limbs.	Protocol
111	Lanefelt, S. V. et al.	2019	Tooth clenching until exhaustion evokes exercise-induced hypoalgesia in healthy persons and in patients with temporomandibular disorders.	Protocol
112	Naugle, K. M. et al.	2014	Self-reported physical activity predicts pain inhibitory and facilitatory function.	Protocol
113	Nie, H. et al.	2009	Temporal summation of pressure pain during muscle hyperalgesia evoked by nerve growth factor and eccentric contractions.	Protocol
114	Nie, H. L. et al.	2005	Delayed onset muscle soreness in neck/shoulder muscles / sourness.	Protocol
115	Assa, T. et al.	2019	The type of sport matters: pain perception of endurance athletes versus strength athletes.	Protocol
116	Astokorki, A. H. Y. et al.	2016	Tolerance of exercise-induced pain at a fixed rating of perceived exertion predicts time trial cycling performance.	Protocol
117	Hidalgo-Lozano, A. et al.	2013	Elite swimmers with and without unilateral shoulder pain: mechanical hyperalgesia and active/latent muscle trigger points in neck-shoulder muscles.	Protocol
118	Hoffman, M. D. et al.	2007	Pain perception after running a 100-mile ultramarathon.	Protocol
119	Hakansson, S., et al.	2018	Intensity-dependent effects of aerobic training on pressure pain threshold in overweight men: a randomized trial.	The data could not be extracted
120	Habechian, F. A. P., et al.	2018	Swimming practice and scapular kinematics, scapulothoracic muscle activity, and the pressure-pain threshold in young swimmers.	Cross-sectional study
121	Grant, S., et al.	2003	Climbing-specific finger endurance: a comparative study of intermediate rock climbers, rowers and aerobically trained individuals.	Protocol
122	Grancharska, K. and N. Pencheva	2009	Pain threshold and pain tolerance in dancers.	Conference abstract
123	Gonglach, A. R., et al.	2013	The effect of submaximal isometric exercise to fatigue on pressure pain threshold in the finger.	Conference abstract
124	Geva, N., et al.	2017	Triathletes lose their advantageous pain modulation under acute psychosocial stress.	Protocol
125	Gerrett, N., et al.	2014	Thermal sensitivity to warmth during rest and exercise: a sex comparison.	Protocol

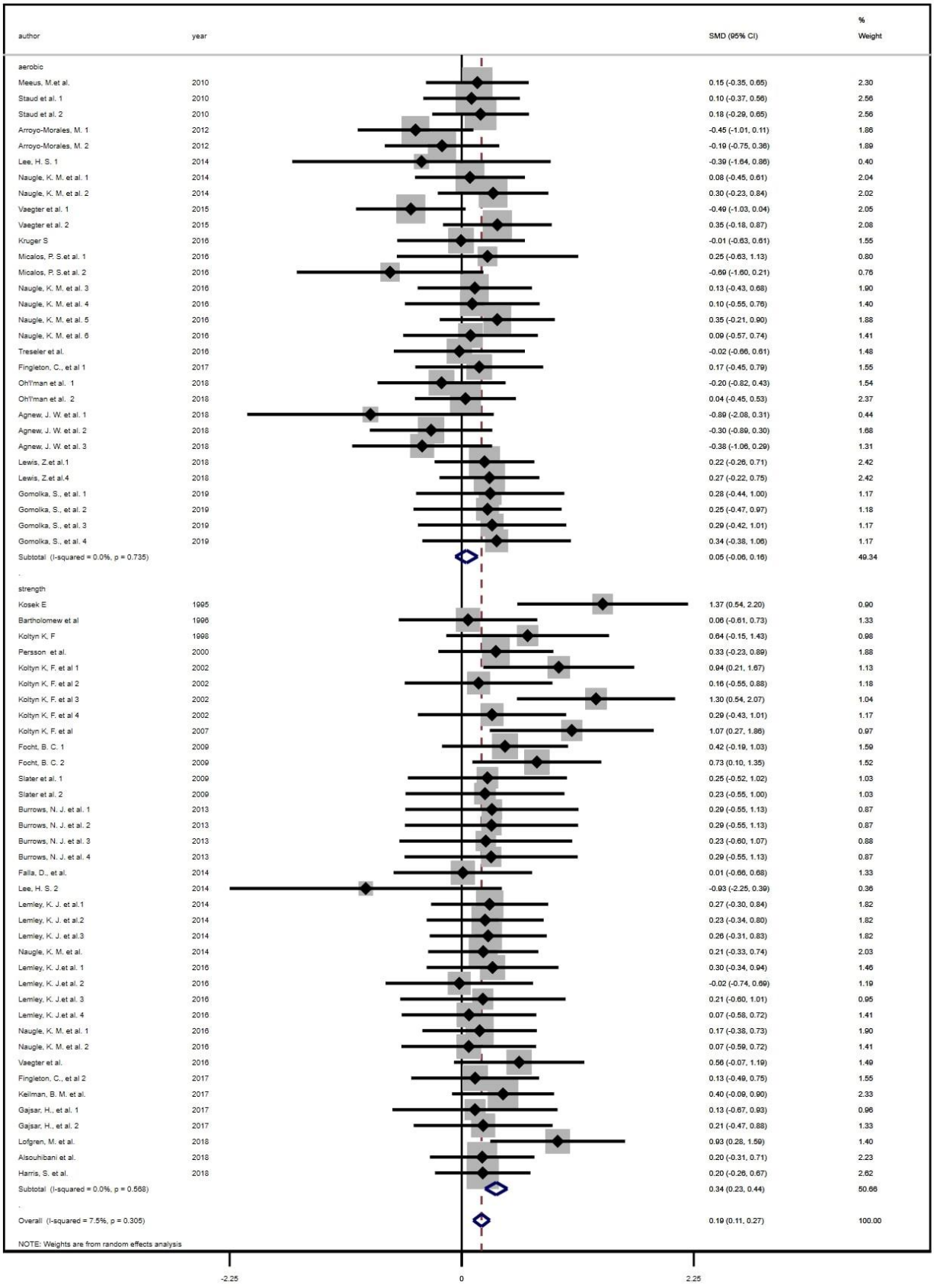
126	George, S. Z., et al.	2006	Immediate effects of spinal manipulation on thermal pain sensitivity: an experimental study.	Protocol
127	Gaudreault, V., et al.	2009	Waist circumference is the best predictor of exercise inappropriate blood pressure response to exercise in subjects with the metabolic syndrome.	Conference abstract
128	Garcin, M., et al.	2005	Use of acetaminophen in young sub-elite athletes.	Conference abstract
129	Fuller, A. K. and M. E. Robinson	1993	A test of exercise analgesia using signal detection theory and a within-subjects design.	Protocol
130	Frutos, A. L., et al.	2012	Pain threshold assessment in relation to neural mobilization therapy.	Protocol
131	Flood, A., et al.	2017	Increased conditioned pain modulation in athletes.	Cross-sectional study
132	Fleckenstein, J., et al.	2017	The pain threshold of high-threshold mechanosensitive receptors subsequent to maximal eccentric exercise is a potential marker in the prediction of DOMS associated impairment.	Protocol
133	Fernández-Carnero, J., et al.	2009	Pressure pain sensitivity mapping for the assessment of muscle hyperalgesia in experimentally induced lateral epicondylalgia.	Protocol
134	Farias, L. F., et al.	2019	Effect of low-volume high-intensity interval exercise and continuous exercise on delayed-onset muscle soreness in untrained healthy males.	Protocol
135	Elsenbruch, S., et al.	2019	Can a brief relaxation exercise modulate placebo or nocebo effects in a visceral pain model?	Protocol
136	Ellingson, L. D., et al	2014	Does exercise induce hypoalgesia through conditioned pain modulation?	Protocol
137	Drinkwater, E. J., et al	2019	Foam rolling as a recovery tool following eccentric exercise: potential mechanisms underpinning changes in jump performance.	Protocol
138	Drewek, B., et al.	2011	Sex differences in pain relief occur following dynamic, but not isometric, exercise.	Conference abstract
139	Domenech-Garcia, V., et al.	2016	Pressure-induced referred pain is expanded by persistent soreness.	Protocol
140	Domenech-Garcia, V., et al.	2018	Pressure-induced referred pain areas are more expansive in individuals with a recovered fracture.	Protocol
141	Dirkwinkel, M., et al.	2008	The influence of repetitive painful stimulation on peripheral and trigeminal pain thresholds.	Protocol
142	Dirkwinkel, M. and S. Evers	2010	The influence of painful stimulation during Asian martial arts training on pain perception.	Article could not be found
143	De La Morena, J. M. D., et al.	2013	Pressure pain mapping of the wrist extensors after repeated eccentric exercise at high intensity.	Protocol
144	De Carvalho, M. R. P., et al.	2005	Effects of supervised cardiovascular training program on exercise tolerance, aerobic capacity, and quality of life in patients with systemic lupus erythematosus.	Protocol
145	Dannecker, E. A., et al.	2008	Appraisals of pain from controlled stimuli: relevance to quantitative sensory testing.	Conference abstract

146	Dannecker, E. A., et al.	2003	Sex differences in delayed onset muscle soreness.	Protocol
147	Dabbs, N. C., et al.	2015	Whole-body vibration while squatting and delayed- onset muscle soreness in women.	Protocol
148	Cotton, V., et al.	2011	The impact of long-term yoga practice on experimental pain perception.	Cross-sectional study
149	Coronado, R. A., et al.	2015	The comparative effects of spinal and peripheral thrust manipulation and exercise on pain sensitivity and the relation to clinical outcome: a mechanistic trial using a shoulder pain model [with consumer summary].	Protocol
150	Cooke, C., et al.	1994	Relationship of performance on the ERGOS work simulator to illness behavior in a workers' compensation population with low back versus limb injury.	Cohort study
151	Cook, D. B., et al.	1998	Sex differences in naturally occurring leg muscle pain and exertion during maximal cycle ergometry.	The data could not be extracted
152	Conti, P. C. R., et al.	2011	Effect of experimental chewing on masticatory muscle pain onset.	Protocol
153	Kemppainen P.	1985	Modification of dental pain and cutaneous thermal sensitivity by physical exercise in man.	Protocol
154	Tae Ho Kim.	2016	The effects of wall slide and sling slide exercises on scapular alignment and pain in subjects with scapular downward rotation.	Protocol
155	Kocur P.	2017	The effect of Nordic walking training on selected upper-body muscle groups in female office workers.	Protocol
156	Kodama N.	2005	Suwaishou-like exercise reduces fatigue and increases pain threshold.	Protocol
157	Koltyn K, F.	2014	Influence of psychosocial variables on exercise-induced hypoalgesia.	Protocol
158	Koltyn K, F.	2002	Exercise induced hypoalgesia and exercise intensity.	Systematic review
159	Komatireddy GR.	1997	Efficacy of low load resistive muscle training in rheumatoid arthritis functional class ii and iii.	Protocol
160	Koutris M.	2009	Effects of intense chewing exercises on the masticatory sensory-motor system.	Protocol
161	Kregel KC	1992	Sympathetic nervous system activity during skin cooling in humans-----relationship to stimulus---intensity & pain sensation.	Protocol
162	Kumar SP.	2011	Efficacy of segmental stabilization exercise for lumbar segmental instability in patients with mechanical low back pain.	Protocol
163	Koltyn K, F.	2012	Temporal summation of heat pain modulated by isometric exercise.	Protocol
164	Kosek E.	2003	Segmental and plurisegmental modulation of pressure	Protocol
165	Kruger S.	2015	Pain thresholds following maximal endurance.	Protocol

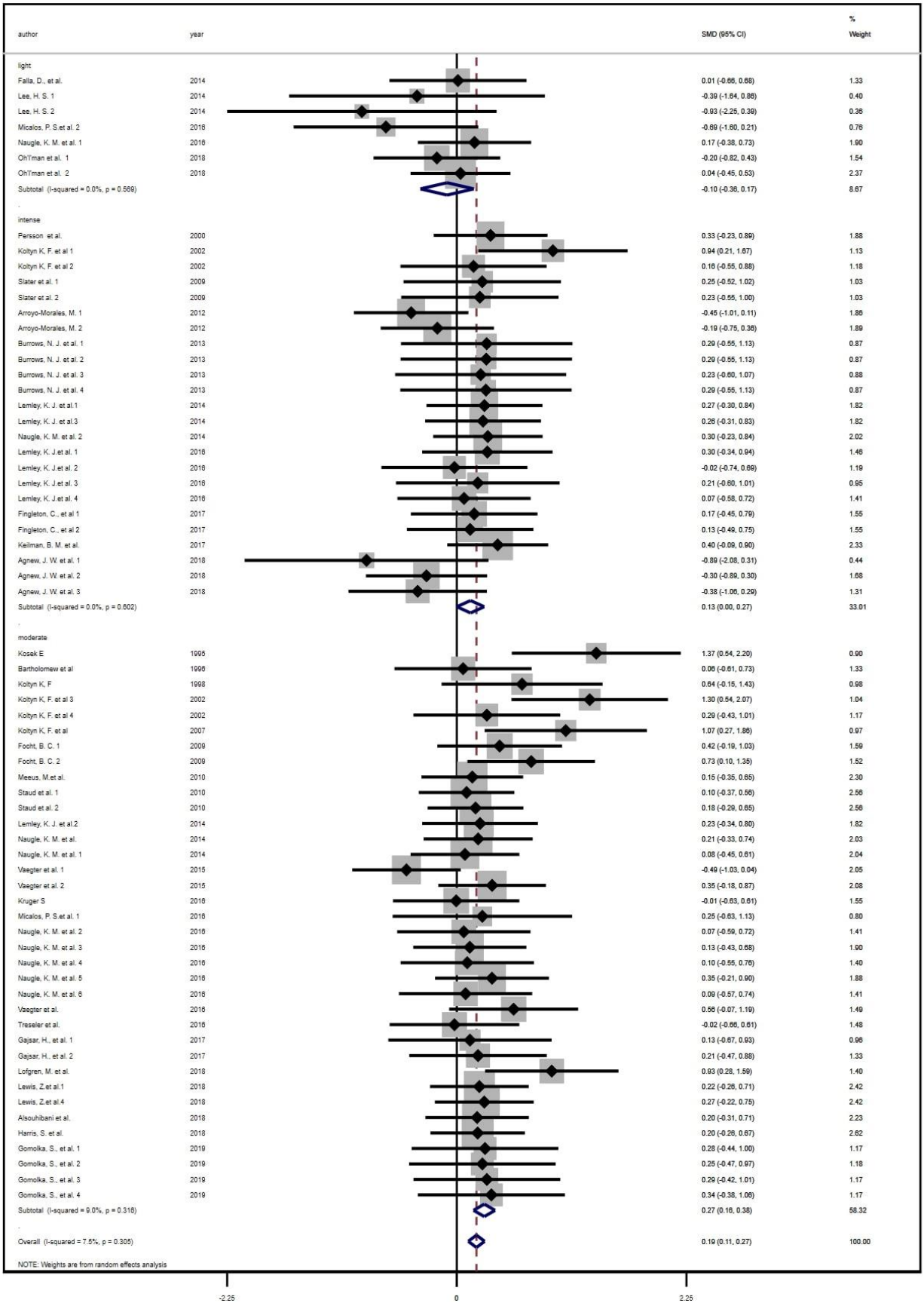
Appendix D. Exercise effects on pain threshold in healthy subjects (n=1326)



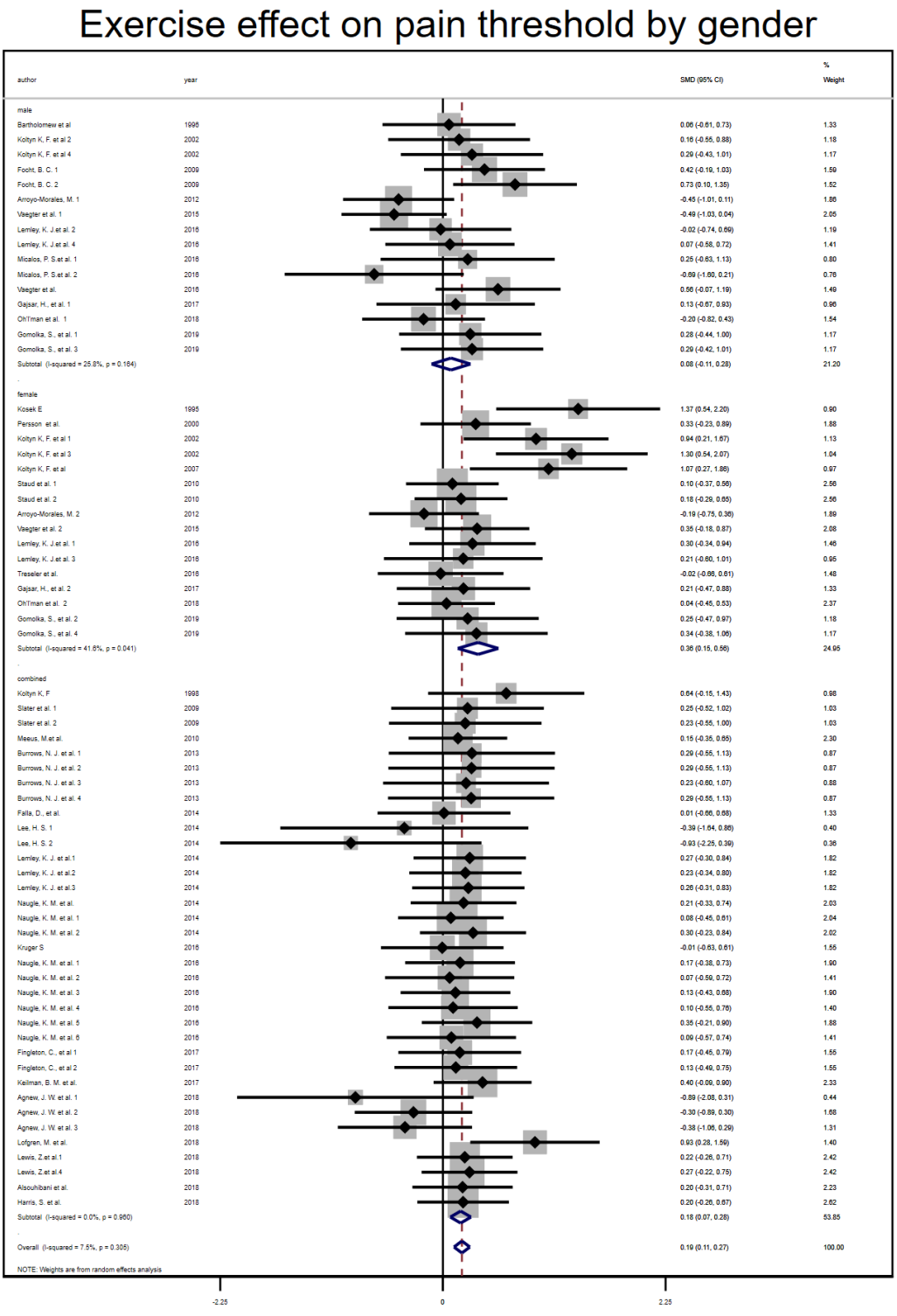
Appendix E. Exercise effects on pain threshold in healthy subjects by exercise type


author
year
SMD (95% CI)
% Weight
aerobic
Meeus, M.et al. 2010 0.15 (-0.35, 0.65) 2.30
Staud et al. 1 2010 0.10 (-0.37, 0.56) 2.56
Staud et al. 2 2010 0.18 (-0.29, 0.65) 2.56
Arroyo-Morales, M. 1 2012 -0.45 (-1.01, 0.11) 1.86
Arroyo-Morales, M. 2 2012 -0.19 (-0.75, 0.36) 1.89
Lee, H. S. 1 2014 -0.39 (-1.64, 0.86) 0.40
Naugle, K. M. et al. 1 2014 0.08 (-0.45, 0.61) 2.04
Naugle, K. M. et al. 2 2014 0.30 (-0.23, 0.84) 2.02
Vaegter et al. 1 2015 -0.49 (-1.03, 0.04) 2.05
Vaegter et al. 2 2015 0.35 (-0.18, 0.87) 2.08
Kruger S 2016 -0.01 (-0.63, 0.61) 1.55
Micalos, P. S.et al. 1 2016 0.25 (-0.63, 1.13) 0.80
Micalos, P. S.et al. 2 2016 -0.69 (-1.60, 0.21) 0.76
Naugle, K. M. et al. 3 2016 0.13 (-0.43, 0.68) 1.90
Naugle, K. M. et al. 4 2016 0.10 (-0.55, 0.76) 1.40
Naugle, K. M. et al. 5 2016 0.35 (-0.21, 0.90) 1.88
Naugle, K. M. et al. 6 2016 0.09 (-0.57, 0.74) 1.41
Treseler et al. 2016 -0.02 (-0.66, 0.61) 1.48
Fingleton, C., et al 1 2017 0.17 (-0.45, 0.79) 1.55
Ohl'man et al. 1 2018 -0.20 (-0.82, 0.43) 1.54
Ohl'man et al. 2 2018 0.04 (-0.45, 0.53) 2.37
Agnew, J. W. et al. 1 2018 -0.89 (-2.08, 0.31) 0.44
Agnew, J. W. et al. 2 2018 -0.30 (-0.89, 0.30) 1.68
Agnew, J. W. et al. 3 2018 -0.38 (-1.06, 0.29) 1.31
Lewis, Z.et al.1 2018 0.22 (-0.26, 0.71) 2.42
Lewis, Z.et al.4 2018 0.27 (-0.22, 0.75) 2.42
Gomolka, S., et al. 1 2019 0.28 (-0.44, 1.00) 1.17
Gomolka, S., et al. 2 2019 0.25 (-0.47, 0.97) 1.18
Gomolka, S., et al. 3 2019 0.29 (-0.42, 1.01) 1.17
Gomolka, S., et al. 4 2019 0.34 (-0.38, 1.06) 1.17
Subtotal (I-squared = 0.0%, p = 0.735) 0.05 (-0.06, 0.16) 49.34
.
strength
Kosek E 1995 1.37 (0.54, 2.20) 0.90
Bartholomew et al 1996 0.06 (-0.61, 0.73) 1.33
Koltyn K. F 1998 0.64 (-0.15, 1.43) 0.98
Persson et al. 2000 0.33 (-0.23, 0.89) 1.88
Koltyn K. F. et al 1 2002 0.94 (0.21, 1.67) 1.13
Koltyn K. F. et al 2 2002 0.16 (-0.55, 0.88) 1.18
Koltyn K. F. et al 3 2002 1.30 (0.54, 2.07) 1.04
Koltyn K. F. et al 4 2002 0.29 (-0.43, 1.01) 1.17
Koltyn K. F. et al 2007 1.07 (0.27, 1.86) 0.97
Focht, B. C. 1 2009 0.42 (-0.19, 1.03) 1.59
Focht, B. C. 2 2009 0.73 (0.10, 1.35) 1.52
Slater et al. 1 2009 0.25 (-0.52, 1.02) 1.03
Slater et al. 2 2009 0.23 (-0.55, 1.00) 1.03
Burrows, N. J. et al. 1 2013 0.29 (-0.55, 1.13) 0.87
Burrows, N. J. et al. 2 2013 0.29 (-0.55, 1.13) 0.87
Burrows, N. J. et al. 3 2013 0.23 (-0.60, 1.07) 0.88
Burrows, N. J. et al. 4 2013 0.29 (-0.55, 1.13) 0.87
Falla, D., et al. 2014 0.01 (-0.66, 0.68) 1.33
Lee, H. S. 2 2014 -0.93 (-2.25, 0.39) 0.36
Lemley, K. J. et al.1 2014 0.27 (-0.30, 0.84) 1.82
Lemley, K. J. et al.2 2014 0.23 (-0.34, 0.80) 1.82
Lemley, K. J. et al.3 2014 0.26 (-0.31, 0.83) 1.82
Naugle, K. M. et al. 2014 0.21 (-0.33, 0.74) 2.03
Lemley, K. J.et al. 1 2016 0.30 (-0.34, 0.94) 1.46
Lemley, K. J.et al. 2 2016 -0.02 (-0.74, 0.69) 1.19
Lemley, K. J.et al. 3 2016 0.21 (-0.60, 1.01) 0.95
Lemley, K. J.et al. 4 2016 0.07 (-0.58, 0.72) 1.41
Naugle, K. M. et al. 1 2016 0.17 (-0.38, 0.73) 1.90
Naugle, K. M. et al. 2 2016 0.07 (-0.59, 0.72) 1.41
Vaegter et al. 2016 0.56 (-0.07, 1.19) 1.49
Fingleton, C., et al 2 2017 0.13 (-0.49, 0.75) 1.55
Keilman, B. M. et al. 2017 0.40 (-0.09, 0.90) 2.33
Gajsar, H., et al. 1 2017 0.13 (-0.67, 0.93) 0.96
Gajsar, H., et al. 2 2017 0.21 (-0.47, 0.88) 1.33
Lofgren, M. et al. 2018 0.93 (0.28, 1.59) 1.40
Alsouhibani et al. 2018 0.20 (-0.31, 0.71) 2.23
Harris, S. et al. 2018 0.20 (-0.26, 0.67) 2.62
Subtotal (I-squared = 0.0%, p = 0.568) 0.34 (0.23, 0.44) 50.66
.
Overall (I-squared = 7.5%, p = 0.305) 0.19 (0.11, 0.27) 100.00
NOTE: Weights are from random effects analysis
-2.25
0
2.25

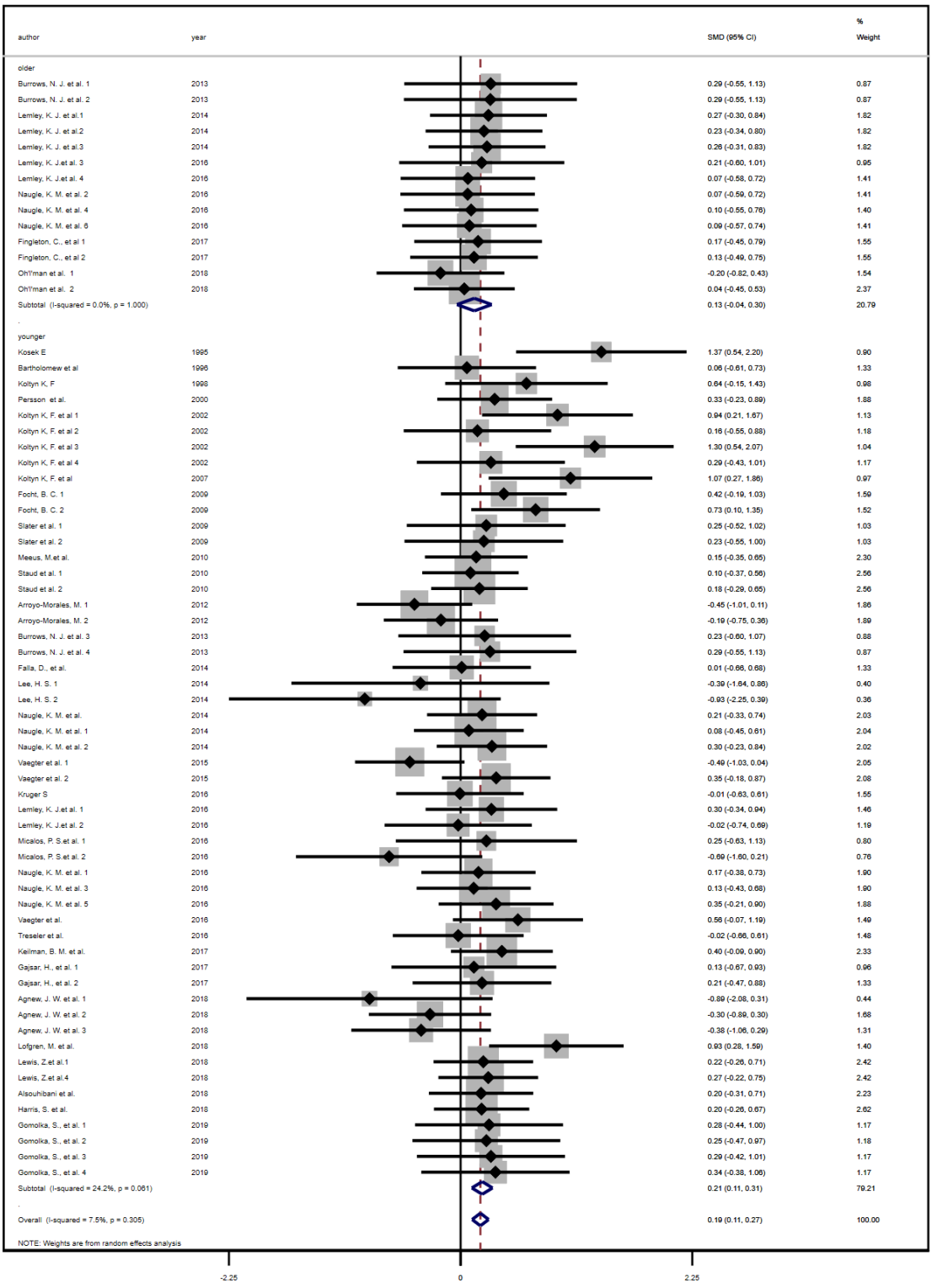
Appendix F. Exercise effects on pain threshold in healthy subjects by exercise intensity



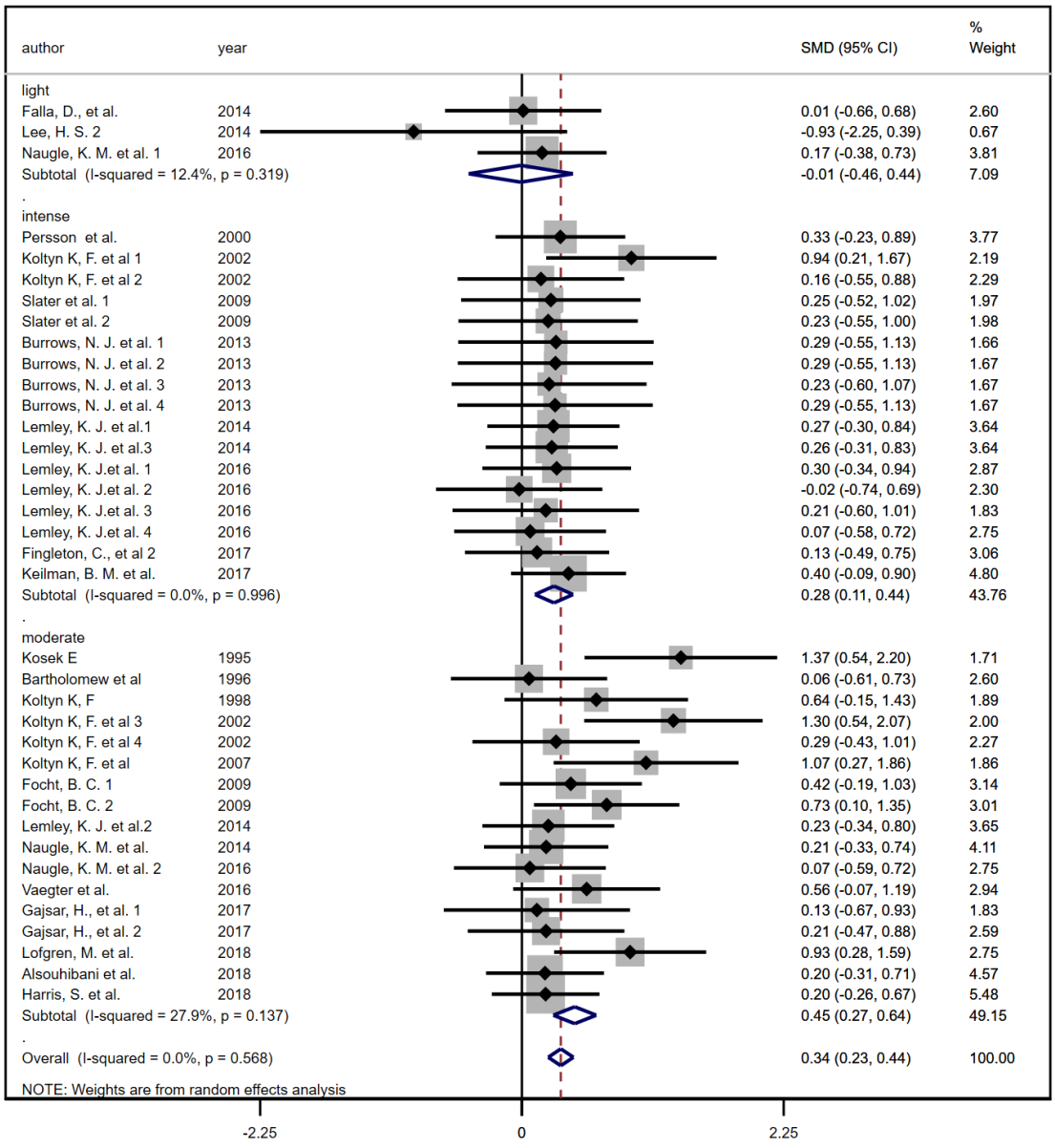
Appendix G: Sub-group analysis and meta-regression.



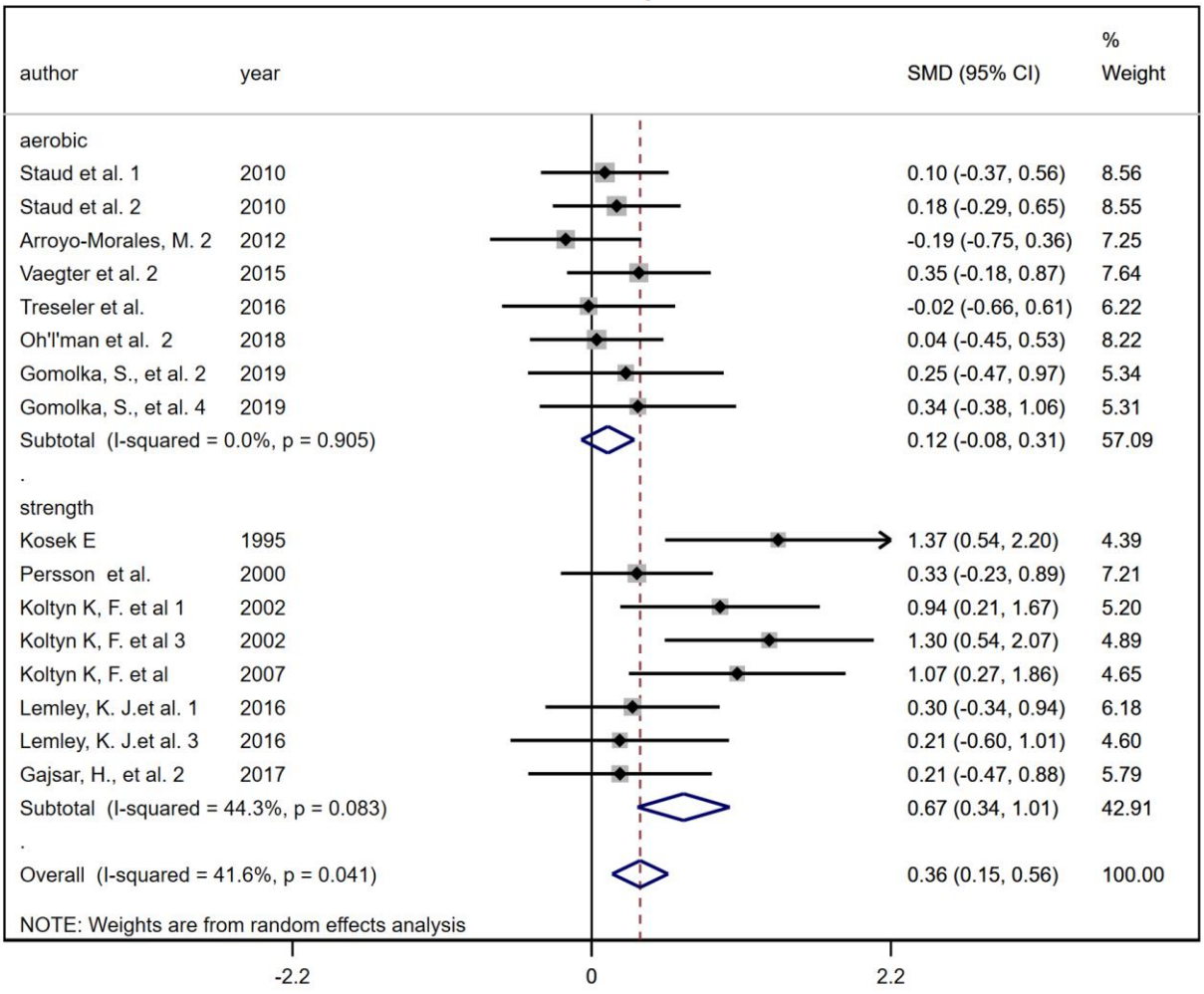
Exercise effect on pain threshold by type of exercise



Exercise effect on pain threshold



Exercise effect on pain threshold



Appendix H: Publication bias.