FACULDADE DE MEDICINA
UNIVERSIDADE DO PORTO

MESTRADO INTEGRADO EM MEDICINA

2019/2020

Maria Margarida Oliveira dos Santos Almeida

Sessões de reeducação da técnica de corrida, com feedback em tempo real, na redução de cargas de impacto: revisão sistemática e meta-análise

Retraining program with real-time feedback for reducing impact-loading variables during running: a systematic review and meta-analysis

Março, 2020

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Mestrado Integrado em Medicina

Área: Ortopedia

Tipologia: Dissertação

Trabalho efetuado sob a Orientação de:
Professor Doutor Manuel António Pereira Gutierres
E sob a Coorientação de:
Professora Bárbara Neves Peleteiro

Trabalho organizado de acordo com as normas da revista:
British Journal of Sports Medicine

Março, 2020

Eu, Maria Margarida Oliveira dos Santos Almeida, abaixo assinado, nº mecanográfico 201403548, estudante do 6º ano do Ciclo de Estudos Integrado em Medicina, na Faculdade de Medicina da Universidade do Porto, declaro ter atuado com absoluta integridade na elaboração deste projeto de opção.

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UC Dissertação/Projeto (6º Ano) – DECLARAÇÃO DE REPRODUÇÃO

NOME

Maria Margarida Oliveira dos Santos Almeida

NÚMERO DE ESTUDANTE	E-MAIL
201403548	mmargaridaalmeida.0.7@gmail.com

DESIGNAÇÃO DA ÁREA DO PROJECTO

Ortopedia

TÍTULO DISSERTAÇÃO/~~MONOGRAFIA~~ (riscar o que não interessa)

Retraining program with real-time feedback for reducing impact-loading variables during running: a systematic review and meta-analysis

ORIENTADOR

Professor Dr. Manuel António Pereira Gutierres

COORIENTADOR (se aplicável)

Professora Bárbara Neves Peleteiro

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É AUTORIZADA A REPRODUÇÃO INTEGRAL DESTE TRABALHO APENAS PARA EFEITOS DE INVESTIGAÇÃO, MEDIANTE DECLARAÇÃO ESCRITA DO INTERESSADO, QUE A TAL SE COMPROMETE.	☐
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Faculdade de Medicina da Universidade do Porto, 25/03/2020

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DEDICATÓRIAS

Aos **meus pais,** pela presença e suporte incondicional em todas as altura,

Aos **meus irmãos**, pelo exemplo que são para mim,

Ao **meu sobrinho**, por me levar a um mundo simples e descomplicado,

Aos **meus amigos de sempre,** por crescerem comigo e me fazerem sempre querer voltar a casa,

Aos **amigos que se juntaram nesta etapa**, por fazerem valer a frase de que Medicina é trabalho em equipa e sozinhos não tem piada nenhuma,

Ao **Dr. Manuel Gutierres**, pelo acompanhamento e ajuda ao longo deste trabalho,

À **professora Bárbara Peleteiro**, por toda a disponibilidade e conhecimento que partilhou desde o primeiro momento.

TITLE: Retraining program with real-time feedback for reducing impact-loading variables during running: a systematic review and meta-analysis

AUTHORS:

Margarida Almeida*
Faculty of Medicine, University of Porto, Porto, Portugal
margaridaosalmeida@gmail.com

Manuel Gutierres, MD PhD*
Faculty of Medicine, University of Porto, Porto, Portugal
mg@med.up.pt

Bárbara Peleteiro*
EPIUnit-Instituto de Saúde Pública, Universidade do Porto, Porto, Portugal
Departamento de Ciências da Saúde Pública e Forenses e Educação Médica, Faculdade de Medicina da Universidade do Porto, Porto, Portugal
barbarap@med.up.pt

José Moreira
Faculty of Medicine, University of Porto, Porto, Portugal
jcpmoreira96@gmail.com

*These authors contributed equally to the manuscript

CORRESPONDING AUTHOR:

Margarida Almeida
Al. Prof. Hernâni Monteiro, 4200 - 319 Porto, PORTUGAL
margaridaosalmeida@gmail.com

KEYWORDS: Gait retraining, running, impact loading, feedback, overuse injuries

WORD COUNT: 3387

ABSTRACT

OBJECTIVE**:** To investigate the effect of retraining programs in combination with real-time feedback for reducing impact-loading variables during running.

DESIGN**:** Systematic review and meta-analysis.

DATA SOURCES**:** PubMed

ELIGIBILITY CRITERIA FOR SELECTING STUDIES**:** Studies on interventions that utilized feedback training during running in regular runners free of injury, of any age, evaluating impact loading or loading rates as outcomes measures.

RESULTS**:** A total of nine articles describing thirteen interventions were obtained through systematic review. Data suitable for meta-analyses on vertical average loading rate (VALR) and for vertical instantaneous loading rate (VILR) were available for thirteen and ten studies, respectively. There was a clear evidence for a positive impact of gait retraining with feedback among runners on reducing both measures (summary Effect Size (ES)=1.43, 95%CI: 1.09, 1.77, I_2 =77.2% for VALR and ES=1.53, 95%CI: 1.12, 1.94, I_2=78.1% for VILR). Stratified analyses showed stronger effects in older participants who run less distance *per* week, on those presenting lower baseline VALR and VILR values, in gait retraining with just one session, with audio-visual feedback, receiving continuous feedback, and with the post-training reassessment during the feedback period or immediately after and which had lower velocity during variables measurements.

CONCLUSION**:** Retraining program in combination with real-time feedback is effective in reducing the impact-loading variables VALR and VILR. Therefore, this strategy is effective to reduce running-related injuries, once higher impact-loading variables are related to it.

MAIN TEXT

INTRODUCTION

Running is a popular sport, due to a low cost, easy accessibility and many health benefits. In the begging, running was a sport almost exclusively for athletes in a competitive context.[1] Nowadays, it has a lot of recreative runners and running events have been growing through the decades in most Western countries, such as city runs, trail runs and obstacle runs.[2]

However, the incidence and prevalence of running-related injuries are high, in particular, overuse injuries due to the repetitive nature of running. Patellofemoral pain, iliotibial band syndrome, medial tibial stress syndrome, tibial stress fracture, Achilles tendinopathy, and plantar fasciitis are common running injuries.[1] The incidence of lower extremity injuries in runners ranges from 20.6% to 79.3%, according to a 2015 systematic review.[2] Stress fractures are also among the most serious overuse injuries, which implicates resting during the recovery time, which averages 8 weeks.[3]

There are multiple risk factors for running lower extremity injuries, including intrinsic, such as anatomy and age, and extrinsic risk factors, like training variables, gait, and biomechanics.[2] Biomechanical factors can interfere in the risk to develop running-related injuries. Kinetics, like impact-related variables, has been associated with running injuries.

During running, each foot impacts the ground with a certain amount of force, which is balanced by an equal and opposite amount of force applied by the ground on the foot. This opposite force is the ground reaction force (GRF), which has various components, being the vertical GRF the greatest in magnitude, related to straight up and down. The GRF is an approximate measure of the loading of the lower-extremity musculoskeletal system and is relatively easy to measure.[4]

The musculoskeletal system is composed of viscoelastic structures that are sensitive to loading rates. As a consequence, the association between greater rates of loading of force and the strain rate experienced by the muscles increases their propensity to injury.[5] Vertical impact variables, such as vertical impact peak (VIP), vertical loading rate (VLR), and tibial shock (TS) have been linked with a variety of injuries, like tibial stress fractures, plantar fasciitis, and patellofemoral pain syndrome.[6] Runners with a history of tibial stress fractures, compared to their healthy controls, exhibited greater vertical rates of loading during the impact phase of stance.[5] This relationship was also reported for runners with a history of plantar fasciitis. The VLR is defined as the slope of the initial part of the vertical GRF-time curve (between the foot strike and the vertical impact peak).[4]

If a runner's mechanics can be modified regarding the impact-related variables, it may be possible to reduce that individual's risk of a stress fracture. With this goal, retraining programs to prevent running-related injuries have been developed. Some studies include feedback in their interventions because the feedback helps the subject to modify their running. The feedback that has the greatest results in decreasing the impact-related variables could be developed and applied to new technologies and be used to professional and recreational runners. Invest in prevention is a good way to reduce running-related injuries, especially with the increasing interest in running.

In a previous review about this subject, the articles included precluded a meta-analysis, due to heterogeneity of study design and outcome measures.[7] This review aimed to evaluate if retraining program in combination with real-time feedback is effective in reducing impact-loading variables during running and which features of participants and of the intervention benefit most.

METHODS

This systematic review and meta-analysis were conducted and reported according to the protocol outlined by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).
A systematic review was performed to identify which interventions that utilized feedback training during running had the most impact in reducing the loading rates. Articles were identified by searching on PubMed, until December 2019. Search terms included: (stress fracture OR bone stress injury OR BSI OR running injur*) AND (runners OR running) AND (impact loading OR loading OR impact OR loading rate OR vertical average loading rate OR vertical instantaneous loading rate OR impact peak OR ground reaction force OR vertical impact peak) AND (randomized controlled trial OR RCT OR controlled clinical trial OR controlled trial OR randomized trial OR intervention OR trial OR randomized OR randomly OR groups). Besides, all reference lists of the selected publications were screened to retrieve additional studies. Two authors (MA, JM) individually screened the studies.

Inclusion and exclusion criteria, selection of studies

For a study to be eligible, each of the following inclusion criteria had to be met (1) study included interventions that utilized feedback training during running, (2) participants were regular runners free of injury at the moment of the study, (3) participants of any age had been included, (4) outcomes included impact loading or loading rates, (5) study was available in full text, (6) publication was written in English, Portuguese or Spanish.

Studies were excluded if any of the following criteria applied (1) study concerned other sport than running, (2) study was not specific about a running population, (3) included military and military-related participants, (4) the type of publication was systematic review, case-report, or ex-vivo experiment.

Data extraction

We extracted data on the following items: authors, publication year, participants' age and gender, sample size, physical characteristics (weight, height, body mass index), weekly running distance, protocol intervention (local of retraining program, dosage, training time, speed during retraining program, running between sessions, instruction/strategy, type of feedback, feedback variable, speeds during baseline and reassessment measures, post-training reassessment, follow-up), outcomes measures and outcomes results. Also, we extracted the baseline, post-training, and 1-month post-training values. When data was not available or in a graphic format, the article authors were contacted to retrieve information.

Meta-analysis

The effect size of each study was calculated by the standardized mean difference between the baseline and post-training values of vertical average loading rate (VALR) and vertical instantaneous loading rate (VILR), which were present in at least half of the articles. Summary effect sizes and corresponding 95% confidence intervals (95%CI) were computed with STATA ®, version 15.1 (StataCorp, College Station, Texas, USA), using random effects methods. Heterogeneity was quantified using the I_2 statistic. Visual inspection of the funnel plots and the Egger's regression asymmetry test were used for assessment of publication bias.

Sensitivity analyses were conducted according to sample size (excluding extremes, *i.e.*, the articles with more and less participants), age group (using the mean as cut-off, <30 years versus >30 years), weekly running distance (using the median as cut-off, <21 km/ week versus >21 km/week versus no information), baseline values (using the mean as cut-off, for VALR <68,022 BW/s versus >68,022 BW/s; for VILR <96,153 versus >96,153), dosage (single session versus multiple sessions), running between sessions (allowed to run versus not allowed to run between sessions), gait retraining site (treadmill vs usual place of running), type of feedback (visual versus audio-visual), feedback removal (faded feedback versus continuous feedback), time of post-training reassessment (during feedback + immediately after feedback period versus pause before measuring post-training variables, without feedback), and velocity during measurements (using the mean as cut-off, <2,92 m/s versus >2,92 m/s versus self-selected speed + no information). It was further evaluated if there was impact when excluding the study with the highest weight [8] and the one that deviates more from the overall result.[9]

RESULTS

Systematic review

One hundred and fifty-six articles were found and screened for eligibility by title and abstract. One hundred and thirty-seven were excluded for not meeting inclusion criteria which left nineteen for full-text analysis. Of those, nine articles were included (Figure 1).

Three studies described different interventions within the same subjects involved, and we considered the results from each intervention. Therefore, a total of thirteen interventions provided in nine articles were included in the meta-analysis.

The selected studies' characteristics, including sample and intervention features, are shown in Table 1. The evaluation periods characteristics, follow-up period, outcomes measures and outcomes are described in Table 2.

Table 1. Summary regarding participant characteristics and protocol intervention in selected studies.

Author	Participant Characteristics				Protocol Intervention			
	n, sex, and age	Control group	Height, weight, and BMI	Weekly mileage	Intervention (local, dosage, session duration, speed during retraining program, running between sessions, and different interventions)	Instruction/ strategy	Type of feedback, variable, and device	Feedback frequency
Bowser et al., 2018 [6]	19 F = 10 M = 9 26,0 y	No	1,75 m 76, 6 kg	25,7 km	Treadmill 8 sessions over 3 weeks; gradually increased from 15 to 30 min over the 8 sessions SSS Not allowed to run between sessions.	Keep the personal TS below a line, placed at 50% of their baseline Make the footfalls softer	Visual GRF (TS) Screen	Faded feedback: gradually removed – last 4 sessions
Chan et al., 2018 [8]	166 F = 84 M = 82 33,6 y	154 matched controls	1,66 m 60 kg	19,5 km	Treadmill 8 sessions over 2 weeks (4 sessions *per* week); gradually increased from 15 to 30 min over the 8 sessions SSS Two speed conditions during baseline and post-training measures: 2A: 8 km/h (slow pace) 2B: 12 km/h (fast pace)	"Run softer" so that the amplitude of vertical impact peak would be reduced or even diminished	Visual GRF (VIP) Screen	Faded feedback: gradually removed – last 4 sessions
Tate and Milner, 2017 [10]	14 F = 10 M = 4 23,7 y	No	1,67 m 60,9 kg	18,7 km	Treadmill Single session; 15 min SSS	Decrease the decibel level as much as possible by trying to run as quietly as possible	Visual Sound intensity of the impact (in decibels) Screen	Continuous real-time feedback
Baggaley et al., 2016 [11]	32 F = 16 M = 16 24,7 y	No	22,72 kg/m2	>16 km	Treadmill Single session SSS (2,9 ± 0,3 m/s) Three different conditions in a randomized order: A: Minimum 7,5% decrease in step length B: Minimum 15% decrease in VALR C: FSA <0º	Get the red cursor located on a horizontal axis inside the target range. A: 7,5 to 12,5% increase in SR B: 15 to 25% decrease in VALR reduction C: FSA between 0 and -10º for FFS	Visual A: SR B: GRF (VALR) C: FSA Screen	Continuous real-time feedback

Table 1. Continued

Author	Participant Characteristics				Protocol Intervention			
	n, sex, and age	Control group	Height, weight, and BMI	Weekly mileage	Intervention (local, dosage, session duration, speed during retraining program, running between sessions, and different interventions)	Instruction/ strategy	Type of feedback, variable, and device	Feedback frequency
Chen et al., 2016 [9]	14 F = 7 M = 7 35,3 y	No	1,70 m 64 kg	19,9 km	Treadmill Single session; 10min feedback period 2,5 m/s Two different conditions in a randomized order: A: rearfoot strike to midfoot strike B: rearfoot strike to forefoot strike	Modify the landing pattern from RFS to MFS and FFS while running at the same speed and cadence for 10 min	Visual and auditory Landing pattern and natural running cadence Screen and metronome	Continuous real-time feedback
Willy et al., 2016 [12]	16 F = 9 M = 7 21,0 y	14 matched controls	23 kg/m2	22,1 km	In-field 8 training runs SSS All the variables were measured in a treadmill	Increase the SR by 7,5% over the preferred SR	Visual SR Wrist computer	Faded feedback**:** only provided on runs 1-3, 5 and 7
Clansey et al., 2014 [13]	12 (M) 33,3 y	10 matched controls	1,8 m 77,2 kg	30,4 km	Treadmill 6 sessions over 3 weeks (2 sessions *per* week); each session: 20 min 3,7m/s Allowed to run between sessions	Find a “strategy or a way” to run within the acceptable shock range (traffic light: green light without sound)	Visual and auditory GRF (PTA) Screen and external speakers	Continuous real-time feedback
Crowell and Davis, 2011 [3]	10 F = 6 M = 4 26 y	No	1,72 m 81,5 kg	>16 km	Treadmill 8 sessions over 2 weeks; gradually increased from 15 to 30 min over the 8 sessions Not allowed to run between sessions	“Run softer” Make the footfalls quieter Keep the acceleration peaks below the line (50% of the mean PPA)	Visual GRF (PTA) Screen	Faded feedback: gradually removed in last 4 sessions
Crowell et al., 2010 [14]	5 (F) 26 y	No	1,64 m 59,3 kg	>32 km	Treadmill Single session; 10 min period feedback SSS (2,4 – 2,6 m/s)	“Run softer” Keep the PPA below the line (50% of the mean PPA)	Visual GRF (PTA) Screen	Continuous real-time feedback

BMI: body mass index; F: Female; FFS: Forefoot strike; FSA: foot strike angle; GRF: Ground reaction force; M: Male; MFS: Midfoot strike; PPA: Peak positive acceleration of the tibia; PTA: Peak tibial acceleration; RFS: Rearfoot strike; SR: Step rate; SSS: Self-selected speed; TS: Tibial shock; VALR: Vertical average loading rate; VIP: Vertical impact peak.

Table 2. Summary regarding evaluation periods, follow-up, outcomes measures and outcomes in selected studies.

Author	Measurement speed	Post-training reassessment	Follow-up	Outcomes measures	Outcomes
Bowser et al., 2018 [6]	3,70 m/s	After the training sessions	1, 6 and 12 months	PFV, TS, VALR, VILR, VIP	Post-control to post-retraining: significant mean differences in TS, VIP, VILR, and VALR; no significant difference in PFV. Post-control to follow-up visits (months 1, 6 and 12): significant mean differences in TS, VIP, VILR, and VALR; no significant difference in PFV.
Chan et al., 2018 [8]	A: 8 km/h B:12 km/h	2 weeks after the first evaluation	-	RRI during the 12-month period, VALR, VILR	Significant interaction effects between training and time for both VALR, and VILR at both speeding tests. Pre-training to post-training: significant reductions in VALR, and VILR in the gait retraining group; no significant reduction in VALR, and VILR in the control group. RRI: 62% lower injury occurrence in gait-retrained runners compared with controls.
Tate and Milner, 2017 [10]	SSS	Immediately after the session	-	VALR, VILR, VIP	Baseline to after gait retraining: significant reductions in VIP, VILR, and VALR.
Baggaley et al., 2016 [11]	SSS (2,9 m/s)	Once the participant was able to consistently meet the feedback target (with feedback)	-	Concentric, and eccentric knee joint work *per* km, concentric, and eccentric ankle joint work *per* km, FSA, step length, VALR	VALR: a significant reduction from baseline to FFS (FSA <0º), SHORT (decrease step length), and LOW IMPACT (decrease VALR) running conditions. A: Baseline to SHORT: significant reduction in step length, eccentric, and concentric knee joint work *per* km; no change in FSA, eccentric, and concentric ankle joint work *per* km. B: Baseline to LOW IMPACT: significant reduction in eccentric knee joint work *per* km; significant increase in eccentric, and concentric ankle joint work *per* km; no change in step length, FSA, and concentric knee joint work *per* km. C: Baseline to FFS: significant reduction in step length, FSA, eccentric, and concentric knee joint work *per* km; significant increase in eccentric, and concentric ankle joint work *per* km.
Chen et al., 2016 [9]	2,5 m/s	During intervention	-	Accumulative probability of TSF, peak AJCF, peak tibial strains, VALR, VILR	Between different landing patterns: significant differences in VALR, VILR, and longitudinal AJCF; no significant differences in anteroposterior and mediolateral AJCF, peak tibial strains, and the probability of TSF at the 100th day of running.

Table 2. Continued

Author	Measurement speed	Post-training reassessment	Follow-up	Outcomes measures	Outcomes
Willy et al., 2016 [12]	3,3 m/s	Post-retraining session	1 month	Knee power absorption, peak HADD, SR, total knee power absorption *per* km of running, VALR, VILR	Significant group x time interactions for SR, VILR, VALR, peak HADD, eccentric knee joint work stance, and eccentric knee joint work *per* km. Pre-training to post-training: a significant increase in SR; significant reductions in VILR, VALR, peak HADD, eccentric knee joint work stance, and eccentric knee joint work *per* km. Pre-training to 1-month post-training: a significant increase in SR; significant reductions in VILR, VALR, peak HADD, eccentric knee joint work stance, and eccentric knee joint work *per* km.
Clansey et al., 2014 [13]	SSS	Post-retraining session within 1-2 days	1 month	AA, FSA, HA, HVV, knee angle, PTA, running economy, VALR, VILR, VIP	Significant group x time interactions for PTA, VALR, VILR, AA, FSA, and HVV. Pre-training to post-training: significant reductions in PTA, VALR, and VILR; no changes in VIP; significant reduction in HVV; no significant difference in HA, knee angle, AA, and FSA. Pre-training to 1-month post-training: a significant reduction in PTA; no significant reductions in VALR, and VILR; no changes in VIP; significant reduction in AA, and FSA; no significant difference in HA, knee angle, and HVV. No significant differences in running economy across time or group-by-time interactions.
Crowell and Davis, 2011 [3]	SSS	One hour after the last session	1 month	PPA, VALR, VILR, VIP	Pre-training to post-training: significant reductions in PPA, VILR, and VALR; no significant reductions in VIP. Pre-training to 1-month post-training: significant reductions in PPA, VILR, VALR, and VIP. Post-training to 1-month post-training: no significant differences in PPA, VILR, VALR, and VIP.
Crowell et al., 2010 [14]	SSS (2,4 – 2,6 m/s)	Immediately after the no-feedback period	-	PPA, VALR, VILR, VIP	End of warm-up to end of the no-feedback period: significant reductions in PPA, VIP, VALR, and VILR (subjects 1 to 4); significant reductions in VIP, VALR, and VILR; no significant difference in PPA (subject 5); a significant increase in PPA, between the ends of warm-up, and feedback periods (subject 4).

AA: ankle angle; AJCF: Ankle joint contact force; FSA: foot strike angle; HADD: Hip adduction; HA: hip angle; HVV: Heel vertical velocity; PFV: Peak vertical force; PPA: Peak positive acceleration of the tibia; PTA: Peak tibial acceleration; RRI: running-related injury; SR: Step rate; SSS: Self-selected speed; TSF: tibial stress fracture; VALR: Vertical average loading rate; VILR: Vertical instantaneous loading rate; VIP: Vertical impact peak.

Meta-analyses for VALR

Thirteen articles were included in the VALR meta-analysis with a total of 532 participants. Overall, the results suggest clear evidence for a positive impact of gait retraining with feedback among runners on reducing their VALR (summary ES=1.43, 95%CI: 1.09, 1.77) (Figure 2A). These values indicate that the summary effect was significant and represented a very large effect size. Heterogeneity was high (I_2=77.2%), and decreased (I_2=44.4%) when excluding the study that deviates more from the overall result [9] leading also to weaker impact (summary ES=1.15, 95%CI: 0.93, 1.37), while no meaningful differences in the heterogeneity (I_2=80.5%) were observed when excluding the study with the highest weight [8], with slightly stronger impact (summary ES=1.61, 95%CI: 1.08, 2.15).

Visual inspection of the funnel plot suggested an underrepresentation of small studies with lower impact, although the Egger's regression asymmetry test (p=0.078) showed no statistically significant publication bias (Figure 3A).

In the stratified analyses (Table 3), heterogeneity between studies was low to high, ranging from 0.0% to 92.0%. The effect of gait retraining with feedback on VALR was stronger in studies with audio-visual feedback (summary ES=2.77, 95%CI: 0.54, 5.00, 3 interventions, I_2=92.0%). Slightly favourable results were observed in studies without sample size extremes (summary ES=1.59, 95%CI: 1.04, 2.15, 10 interventions, I_2=82.1%), including older patients (summary ES=1.77, 95%CI: 1.14, 2.40, 8 interventions, I_2=88.7%), in those who run less distance *per* week (summary ES=1.89, 95%CI: 1.27, 2.51, 5 interventions, I_2=88.4%) and started with smaller baseline VALR values (summary ES=1.62, 95%CI: 1.03, 2.21, 8 interventions, I_2=86.1%), in gait retraining with just one session (summary ES=1.90, 95%CI: 1.08, 2.72, 7 interventions, I_2=87.6%), receiving continuous feedback (summary ES=1.74, 95%CI: 1.01, 2.47, 8 interventions, I_2=86.0%), and with post-training reassessment during feedback period or immediately after (summary ES=1.90, 95%CI: 1.08, 2.72, 7 interventions, I_2=87.6%), and in which baseline and reassessment measurements were performed with less velocity (summary ES=1.76, 95%CI: 1.10, 2.42, 7 interventions, I_2=87.9%). Results remained similar when restricting the analysis to studies that performed the gait retraining in treadmill (summary ES=1.46, 95%CI: 1.10, 1.82, 12 interventions, I_2=79.1%), as well as in those interventions with multiple sessions who had no freedom to run between sessions (summary ES=1.43, 95%CI: 0.85, 2.02, 2 interventions, I_2=1.7%).

Table 3. Sensitivity analyses for vertical average loading rate (VALR) and vertical instantaneous loading rate (VILR).

		VALR			VILR		
		Number of interventions	Summary ES (95%CI)	I_2 (%)	Number of interventions	Summary ES (95%CI)	I_2 (%)
Overall		13	1.43 (1.09, 1.77)	77.2	10	1,53 (1.12, 1.94)	78.1
Sample size							
	Without the extremes[8, 14]	10	1.59 (1.04, 2.15)	82.1	7	1.84 (1.08, 2.60)	80.1
Age group							
	< 30 years	5	1.25 (0.86, 1.64)	58.4	5	1.39 (1.00, 1.78)	0.2
	> 30 years	8	1.77 (1.14, 2.40)	88.7	5	1.62 (1.01, 2.23)	88.5
Weekly milleage							
	< 21 km/week	5	1.89 (1.27, 2.51)	88.4	5	1.74 (1.13, 2.34)	88.4
	> 21 km/week	3	1.08 (0.65, 1.52)	0.0	3	1.04 (0.60, 1.47)	0.0
	No information	5	1.29 (0.65, 1.92)	75.3	2	2.19 (1.29, 3.10)	0.0
Baseline VALR							
	< 68.022 BW/s	8	1.62 (1.03, 2.21)	86.1	-	-	-
	>68.022 BW/s	5	1.24 (1.04, 1.44)	0.0	-	-	-
Baseline VILR							
	< 96.153 BW/s	-	-	-	6	2.23 (1.26, 3.20)	86.9
	> 96.153 BW/s	-	-	-	4	1.02 (0.82, 1.22)	0.0
Dosage							
	Single session	7	1.90 (1.08, 2.72)	87.6	4	2.67 (1.36, 3.98)	80.4
	Multiple sessions	6	1.15 (1.00, 1.31)	0.0	6	1.03 (0.88, 1.18)	0.8
Run between sessions							
	Allowed	2	0.99 (0.43, 1.54)	0.0	2	0.89 (0.34, 1.44)	0.0
	Not allowed	2	1.43 (0.85, 2.02)	1.7	2	1.59 (0.77, 2.41)	41.4
	No information	2	1.15 (0.98, 1.31)	0.0	2	1.00 (0.84, 1.17)	0.0
	Single session	7	1.90 (1.08, 2.72)	87.6	4	2.67 (1.36, 3.98)	80.4
Retraining local							
	Treadmill	12	1.46 (1.10, 1.82)	79.1	9	1.61 (1.16, 2.05)	80.5
Type of feedback							
	Visual	10	1.18 (0.85, 1.41)	47.7	7	1.10 (0.90, 1.29)	18.0
	Audio-visual	3	2.77 (0.54, 5.00)	92.0	3	2.59 (0.48, 4,69)	91.6
Feedback removal							
	Faded feedback	5	1.17 (1.01, 1.32)	0.0	5	1.05 (0.88, 1.22)	8.9
	Continuous feedback	8	1.74 (1.01, 2.47)	86.0	5	2.24 (1.03, 3.46)	84.6
Post-training reassessment							
	During feedback period/ immediately after	7	1.90 (1.08, 2.72)	87.6	4	2.67 (1.36, 3.98)	80.4
	After a break	6	1.15 (1.00, 1.31)	0.0	6	1.03 (0.88, 1.18)	0.8
Measurement speed							

	< 2,92 m/s	7	1.76 (1.10, 2.42)	87.9	4	2.57 (0.93, 4.20)	91.5
	> 2,92 m/s	3	1.20 (0.99, 1.41)	0.0	3	1.04 (0.83, 1.25)	0.0
	No information	3	1.31 (0.69, 1.92)	29.6	3	1.32 (0.56, 2.08)	52.9

Four interventions [3, 6, 12, 13] performed a follow-up after for one month, and overall, the results suggest the persistence of a positive impact after one month of gait retraining with feedback (summary ES=1.02, 95%CI: 0.51, 1.53, I_2=38.9%) .

Meta-analyses for VILR

Regarding the meta-analysis for VILR, one study and the corresponding three interventions were not included because VILR was not an outcome. Therefore, ten interventions were included in the meta-analysis with a total of 436 participants. Overall, we observed a decrease in VILR with the gait retraining with feedback (summary ES=1.53 95%CI: 1.12, 1.94) (Figure 2B), with high heterogeneity (I_2=78.1%). When excluding the study that deviates more from the overall result,[9] heterogeneity decreased (I_2=13.0%), and a weaker impact was observed (summary ES=1.07, 95%CI: 0.89, 1.25). No meaningful differences in the heterogeneity (I_2=77.4%) were observed when excluding the study with the highest weight,[8] with slightly stronger impact (summary ES=1.88, 95%CI: 1.17, 2.59).

Visual inspection of the funnel plot suggested an underrepresentation of small studies with lower impact, as confirmed by the Egger's regression asymmetry test (p=0.022) for statistically significant publication bias (Figure 3B).

Overall, heterogeneity remained low to high, ranging 0.0% to 91.6%, in the stratified analyses (Table 3). The effect of gait retraining with feedback on VILR was stronger in interventions that started with smaller baseline VILR values (summary ES=2.23, 95%CI: 1.26, 3.20, 6 interventions, I_2=86.9%), in gait retraining with just one session (summary ES=2.67, 95%CI: 1.36, 3.98, 4 interventions, I_2=80.4%), with audio-visual feedback (summary ES=2.59, 95%CI: 0.48, 4.69, 3 interventions, I_2=91.6%), receiving continuous feedback (summary ES=2.24, 95%CI: 1.03, 3.46, 5 interventions, I_2=84.6%), with post-training reassessment during feedback period or immediately after (summary ES=2.67, 95%CI: 1.36, 3.98, 4 interventions, I_2=80.4%), and in which baseline and reassessment measurements were performed with less velocity (summary ES=2.57, 95%CI: 0.93, 4.20, 4 interventions, I_2=91.5%). Slightly favourable results were observed in studies without sample size extremes (summary ES=1.84, 95%CI: 1.08, 2.60, 7 interventions, I_2=80.1%), including older patients (summary ES=1.62, 95%CI: 1.01, 2.23, 5 interventions, I_2=88.5%), in those who run less distance *per* week (summary ES=1.74, 95%CI:

1.13, 2.34, 5 interventions, I^2=88.4%), when restricting the analysis to studies that performed the gait retraining in treadmill (summary ES=1.61, 95%CI: 1.16, 2.05, 9 interventions, I^2=80.5%), and in those interventions with multiple sessions who had no freedom to run between sessions (summary ES=1.59, 95%CI: 0.77, 2.41, 2 interventions, I^2=41.4%).

Four interventions [3, 6, 12, 13] performed a follow-up after for one month, and overall, the results suggest the persistence of a positive impact after one month of gait retraining with feedback (summary ES=1.02, 95%CI: 0.54, 1.49, I^2=29.5%).

DISCUSSION

The main findings of these meta-analyses indicate that retraining program in combination with real-time feedback reduced the impact-loading variables VALR and VILR, especially in older patients, who run less distance *per* week, with lower baseline VALR and VILR values, in a retraining program with a single session, in a treadmill, with an audio-visual and receiving continuous feedback. The effect was also stronger when the post-training reassessment occurred during the feedback period or immediately after and when the velocity was lower during baseline and reassessment measures. In those retraining programs with multiple sessions, there is a significant reduction in VILR when running is not allowed between sessions. The main findings are in agreement with the previous systematic review.[7] Nevertheless, due to the high heterogeneity between studies found, summary effect size estimates should be interpreted with caution. Furthermore, although statistical evidence of publication bias was observed only for VILR, overall our results are suggestive of the existence of an underrepresentation of small studies with negative effects.

Even if the variables selected for meta-analysis needed to be present in at least half of the articles for sounded quantitative analysis, among the pooled group of studies post strict inclusion criteria, some amount of unexplained heterogeneity was still observed. To evaluate the cause of heterogeneity, subgroup analyses were performed. These sensitivity analyses were carried out also in order to identify methodological issues or exposure conditions that potentially had greater influence in the effect of retraining program with real-time feedback on impact-loading variables.

When excluding the studies with more and fewer participants no significant change in heterogeneity was observed as well as the summary effect size remained unaltered. The mean number of participants, without these two studies, was 40.9 participants, and the study with less and more participants had 5 and 166, respectively, with point estimates similar to the overall effect size.

The benefits of retraining programs with real-time feedback are influenced by age, by weekly running distance and by baseline impact-loading values. However, age and distance training have not yet been identified as risk factors.[2] Possibly, the ones with less running distance *per* week are also the ones with less running experience, and so can modify their running pattern easier than the experienced ones. It has been already recognized that higher values of VALR and VILR are associated with a higher risk of some running injuries. In our subgroup analyses, the effect was still positive within higher baseline values, but the lack of information on how long the participants had been running could have provided further insights, since there is a risk factor for some running injuries.[2]

The sensitivity analysis according to intervention protocol showed that single sessions and continuously receiving feedback lead to a greater effect size on both VALR and VILR. Also, doing the post-training reassessment during the feedback period or immediately after showed more favourable results. Nevertheless, in all these categories, these three subgroups are the ones presenting the highest heterogeneity. It would be expectable that gait retraining that includes multiple practice sessions in which feedback is gradually removed may result in persistence of gait changes,[3] and so, even with a pause between feedback period and the post-training reassessment, the difference between baseline and post-training values would be greater. In the previous systematic review,[7] there was no clear indication that one specific format of feedback was superior to another, despite all had positive effects. However, all the studies that had just a single session also measured the post-training variables during the period feedback or immediately after this period, which favours a greater difference between baseline values. Only one study [13] among those receiving feedback continuously did not have these two features (single session and closer post-training reassessment). These facts may explain the findings. It seems plausible, that the closer the post-training reassessment to the continuous feedback period, the greater the persistence of the gait changes, and so greater the effect size in these subgroups.

Regarding the real-time feedback features, audio-visual feedback resulted in greater effect size. Indeed, audio-visual feedback turns out to be double feedback contributing to this result. However, further studies with audio-visual feedback are necessary as just two studies adopted this type of feedback. Clansey et al.[13] suggested using auditory feedback over visual feedback systems because of its superior capability of being transferred into an outdoor setting via a portable headphone system, and these findings support this idea.

The interventions with multiple sessions showed more favourable results when running between sessions was not allowed. Possibly, this allowed the participants not to regress to their usual running pattern, while not retaining the new skills, being this a possible explanation for the improved retention in this subgroup.

It is reasonable to accept that the difference between baseline and post-training is higher when the velocity during measurements is lower since this velocity conditions lower VALR and VILR values.[8] So, if there is a higher impact in the lower baseline values, it is likely that lower velocity during measurements has a higher effect size.

While the effect of retraining local on VILR was more pronounced when restricting to treadmill interventions, no modification of the outcome was found for VALR. These small differences for the treadmill favour to future apply these gait retraining outside the experimental and clinical context, especially taking into account the lack of studies with an in-field protocol.

After one month follow-up, the results remained positive, which suggested the persistence of alterations during running, although the effect seems to decrease over time. The two interventions [3, 6] showing stronger effects had in common the use of tibial shock as a feedback variable, suggesting that this may result in the persistence of gait changes for a longer time. However, more studies are needed to certify this association.

In this systematic review, one single [13] intervention did not show a reduction either in VALR nor VILR. Indeed, this intervention was the only in which the participants did not receive verbal instruction besides finding their own "strategy or way". This could explain the lack of effect. Also, one intervention (A) [11] which just had the outcome VALR, did not observe a reduction. The difference between this intervention and the ones of the same study was the running condition. The feedback variable in this intervention was the step rate. Comparing with the other intervention that used step rate as feedback, both of them asked for a 7.5% increase in step rate; the difference between them was the number of sessions. The one without reduction [11] in VALR just had one session, while the intervention with positive results [12] had multiple sessions. Therefore, positive results using the step rate as a feedback variable may only be apparent after more than one session.

Finally, the lack of homogeneity among the analysed studies, especially in the timing of measuring baseline and post-training values, supports the need for more studies in this area. Also, all the subgroups that benefit more are the ones showing higher heterogeneity and, consistently, Chen et al.[9] is part of these groups, which is the one that departs most from the final result. However, there was no evident reason to exclude this article.

CONCLUSION

The retraining program in combination with real-time feedback is effective in reducing the impact-loading variables VALR and VILR. Thereafter, this strategy is effective to reduce running-related injuries, once higher impact-loading variables are related to it. Developing wearable technologies and new gadgets would enable real-time feedback on certain components of gait, allowing for gait retraining to be conducted outside the laboratory or clinic, offering the potential to perform gait retraining in-field in professional and recreative runners.[12] The beneficial effects, with more or less power, extend to all categories that had been tested.

COMPETING INTERESTS

The authors report no conflicts of interest.

REFERENCES

1. Ceyssens L, Vanelderen R, Barton C, et al. Biomechanical Risk Factors Associated with Running-Related Injuries: A Systematic Review. *Sports Med* 2019;49(7):1095-115.
2. van der Worp MP, ten Haaf DS, van Cingel R, et al. Injuries in runners; a systematic review on risk factors and sex differences. *PLoS One* 2015;10(2):e0114937.
3. Crowell HP, Davis IS. Gait retraining to reduce lower extremity loading in runners. *Clin Biomech (Bristol, Avon)* 2011;26(1):78-83.
4. Zadpoor AA, Nikooyan AA. The relationship between lower-extremity stress fractures and the ground reaction force: a systematic review. *Clin Biomech (Bristol, Avon)* 2011;26(1):23-8.
5. Davis IS, Bowser BJ, Mullineaux DR. Greater vertical impact loading in female runners with medically diagnosed injuries: A prospective investigation. *British Journal of Sports Medicine* 2016;50(14):887-92.
6. Bowser BJ, Fellin R, Milner CE, et al. Reducing Impact Loading in Runners: A One-Year Follow-up. *Med Sci Sports Exerc* 2018;50(12):2500-06.
7. Agresta C, Brown A. Gait retraining for injured and healthy runners using augmented feedback: a systematic literature review. *journal of orthopaedic & sports physical therapy* 2015;45(8):576-84.

8. Chan ZYS, Zhang JH, Au IPH, et al. Gait Retraining for the Reduction of Injury Occurrence in Novice Distance Runners: 1-Year Follow-up of a Randomized Controlled Trial. *Am J Sports Med* 2018;46(2):388-95.
9. Chen TL, An WW, Chan ZYS, et al. Immediate effects of modified landing pattern on a probabilistic tibial stress fracture model in runners. *Clin Biomech (Bristol, Avon)* 2016;33:49-54.
10. Tate JJ, Milner CE. Sound-Intensity Feedback During Running Reduces Loading Rates and Impact Peak. *J Orthop Sports Phys Ther* 2017;47(8):565-69.
11. Baggaley M, Willy RW, Meardon SA. Primary and secondary effects of real-time feedback to reduce vertical loading rate during running. *Scand J Med Sci Sports* 2017;27(5):501-07.
12. Willy RW, Buchenic L, Rogacki K, et al. In-field gait retraining and mobile monitoring to address running biomechanics associated with tibial stress fracture. *Scand J Med Sci Sports* 2016;26(2):197-205.
13. Clansey AC, Hanlon M, Wallace ES, et al. Influence of tibial shock feedback training on impact loading and running economy. *Med Sci Sports Exerc* 2014;46(5):973-81.
14. Crowell HP, Milner CE, Hamill J, et al. Reducing impact loading during running with the use of real-time visual feedback. *J Orthop Sports Phys Ther* 2010;40(4):206-13.

FIGURE LEGENDS

FIGURE 1:

Flow diagram indicating the number of studies retrieved on the literature search, and the final number of studies included in the meta-analysis.

FIGURE 2A:

Forrest plot for the impact of retraining program with real-time feedback on the vertical average loading rate (VALR).

FIGURE 2B:

Forrest plot for the impact of retraining program with real-time feedback on the vertical instantaneous loading rate (VILR).

FIGURE 3A:

Impairment meta-analysis funnel plot for vertical average loading rate (VALR) evaluating publication bias. Each circle denotes an individual study with a specific effect size (x-axis) and standard error (y-axis).

FIGURE 3B:

Impairment meta-analysis funnel plot for vertical instantaneous loading rate (VILR) evaluating publication bias. Each circle denotes an individual study with a specific effect size (x-axis) and standard error (y-axis).

FIGURES

FIGURE 1:

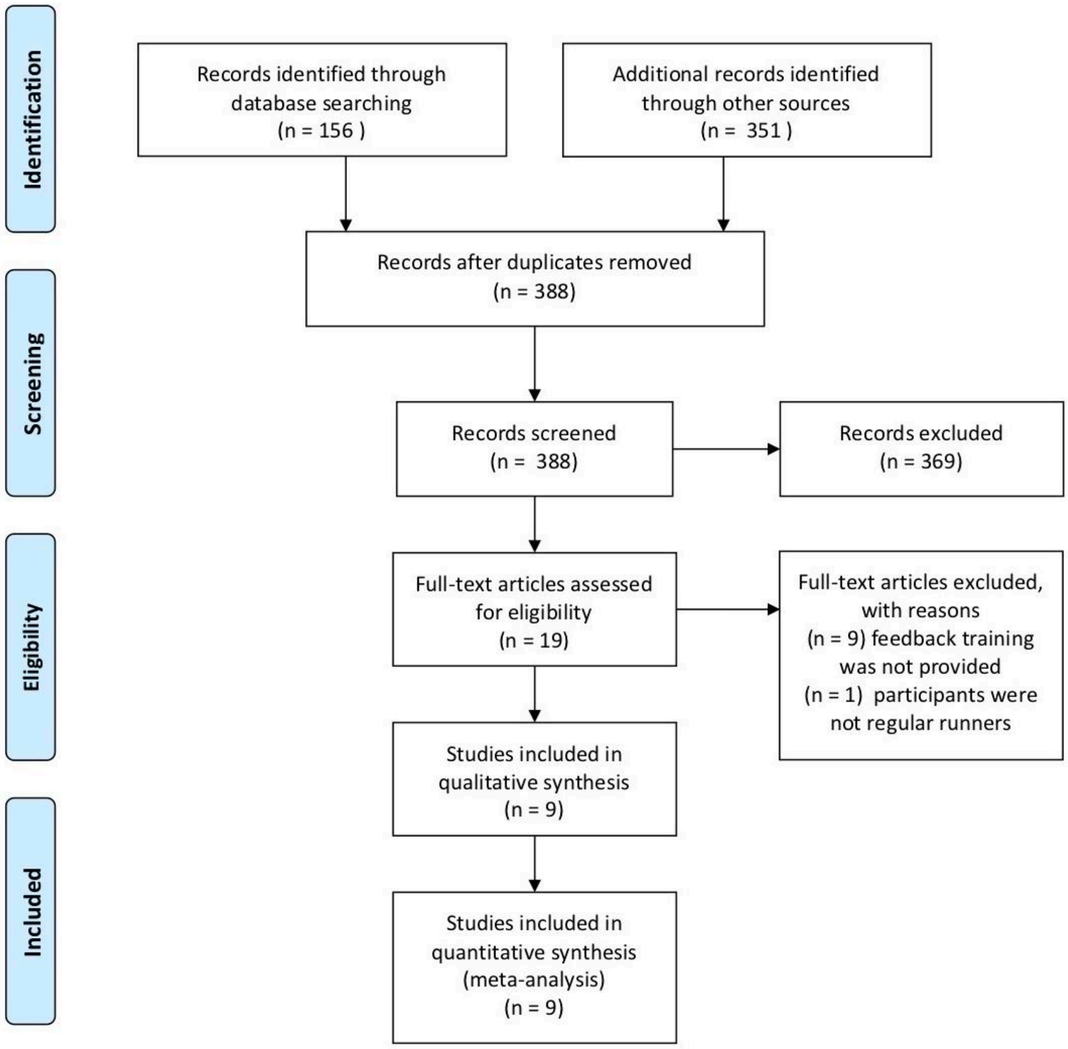


FIGURE 2A:

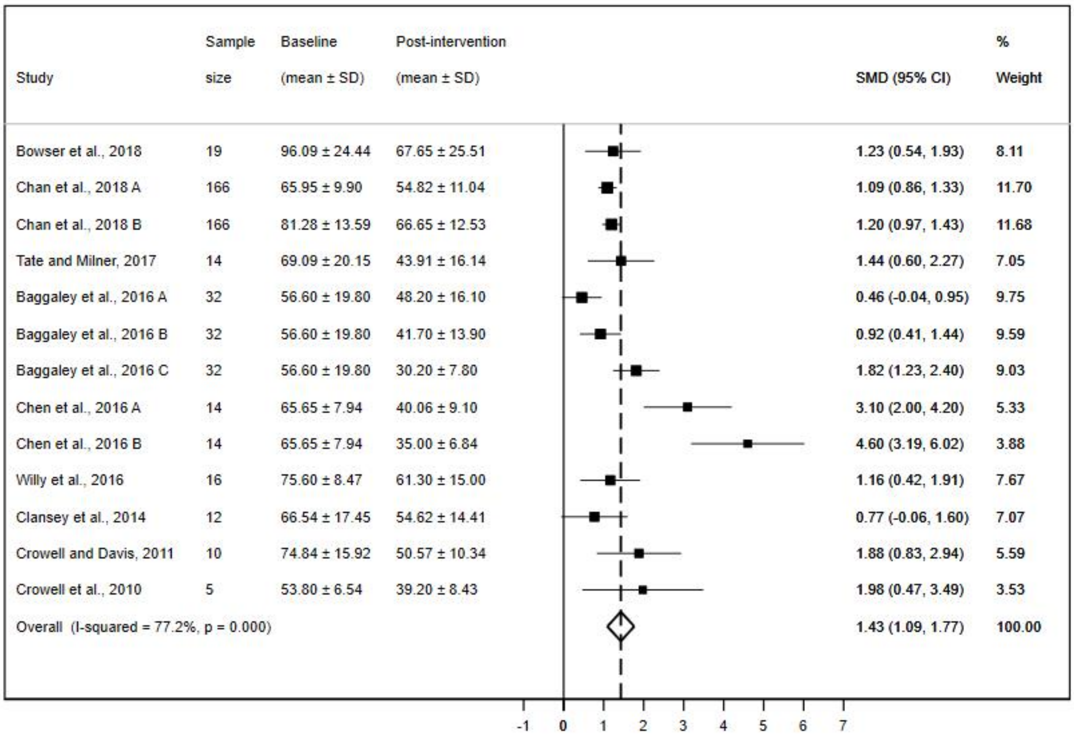


FIGURE 2B:

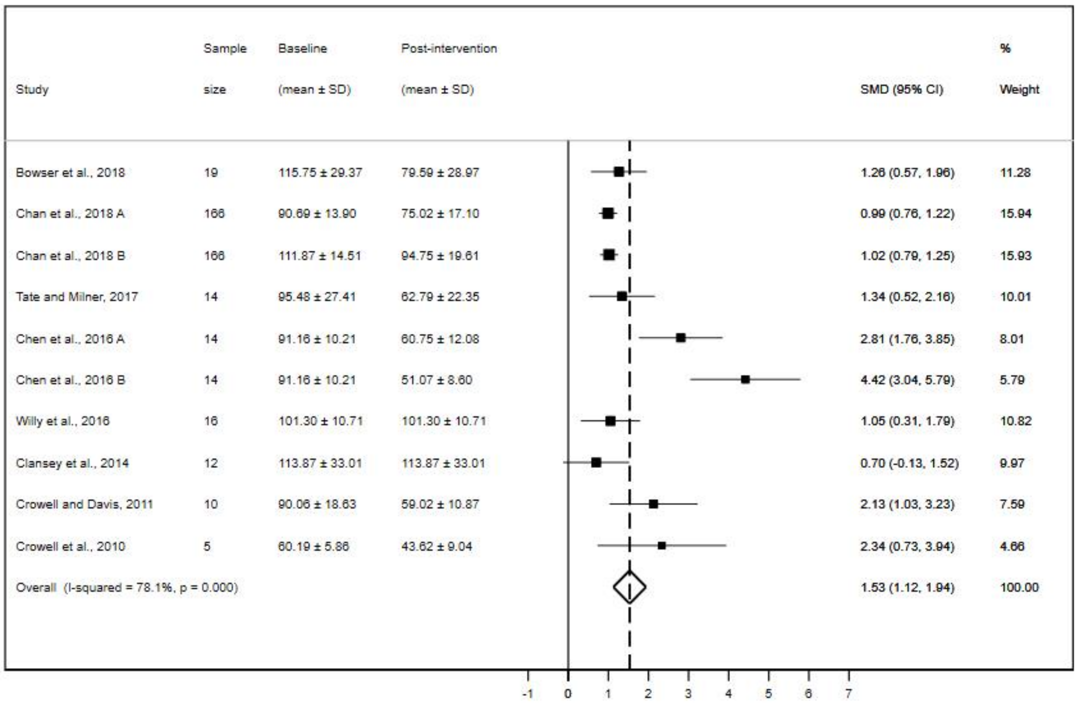


FIGURE 3A:

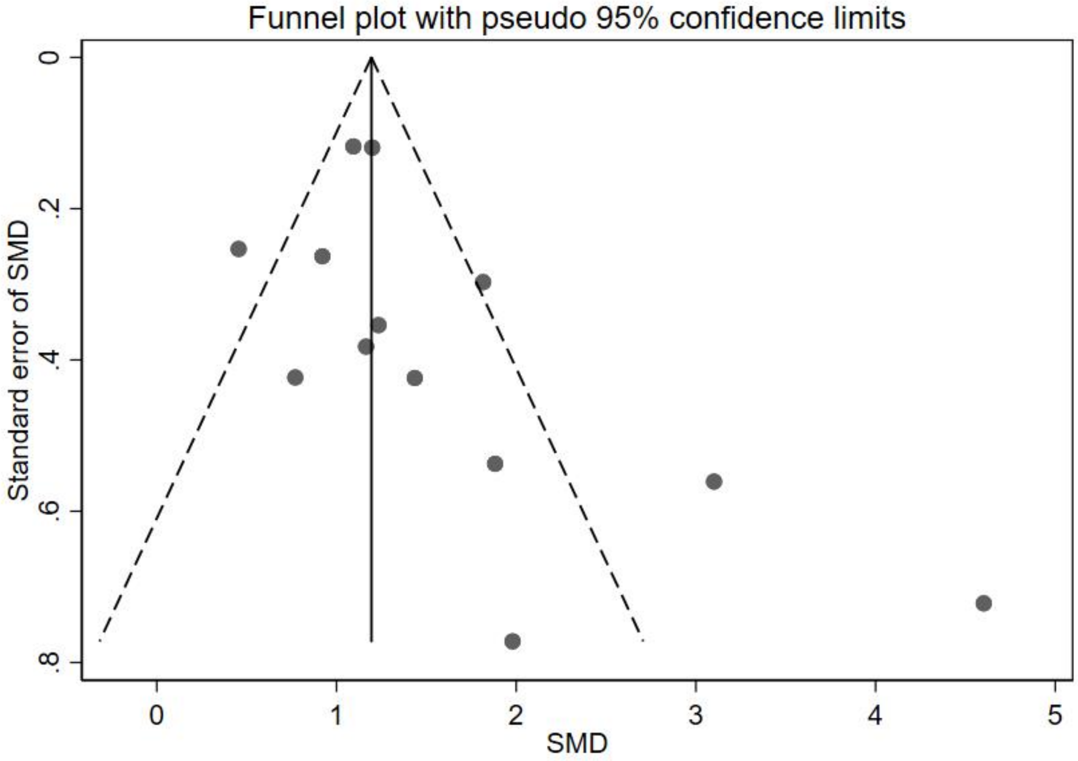
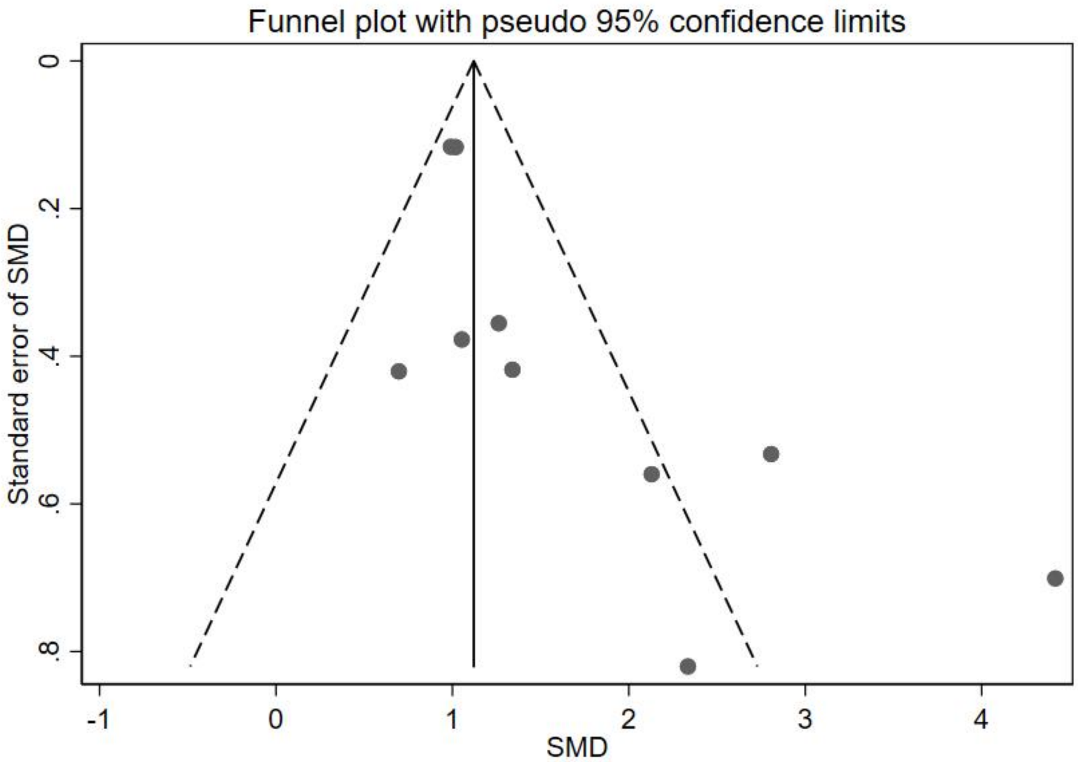


FIGURE 3B:



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