Health benefits of hard martial arts in adults: a systematic review

Article *in* Journal of Sports Sciences · November 2017

DOI: 10.1080/02640414.2017.1406297

4 authors:

Sandra Origua
Deakin University
2 PUBLICATIONS **26** CITATIONS
SEE PROFILE

Jennifer Marks
Australian Catholic University
18 PUBLICATIONS **166** CITATIONS
SEE PROFILE

Isaac Estevan
University of Valencia
92 PUBLICATIONS **1,014** CITATIONS
SEE PROFILE

Lisa Michele Barnett
Deakin University
267 PUBLICATIONS **9,930** CITATIONS
SEE PROFILE

G0'(,? H0&0)/,- #) ?'%E @ '%,/'('%,- /& 'E$(,-3 ' -I-,0 @ ',/. %0J/0C

*'&E%' >%/A$' K/#-L "0&&/)0% M '%N-L 1-''. O-,0J'& P Q/-' MD R'%&0,,

S# ./,0 ,?/- '%,/.(03 "#$%&# '&()*# +(,-. /0$$(10& 2#&3-. 4-##5 6-708#$ 9 :(-# 2; <#&$077 =>?@ABC D0#E7F G0$01(7- ,1 F#&% H#&7(#E #&7- ($ #%*E7-C # -I-70H#7(5 &08(0J. /,*&$#E ,1 "K,&7- "5(0$50-

S# (/&N ,# ,?/- '%,/.(03 https://doi.org/10.1080/02640414.2017.1406297

Published online: 21 Nov 2017.

JOURNAL OF SPORTS SCIENCES, 2017
https://doi.org/10.1080/02640414.2017.1406297

Routledge
Taylor & Francis Group

Health benefits of hard martial arts in adults: a systematic review

Sandra Origua Rios[a], Jennifer Marks [a], Isaac Estevan [b] and Lisa M. Barnett[a]

[a]School of Health and Social Development, Deakin University, Geelong Australia; [b]Department of Teaching of Music, Visual and Corporal Expression, University of Valencia, Valencia, Spain

ABSTRACT

Participation in organized sports is promoted as a means of increasing physical activity levels and reducing chronic disease risk in adults. Hard martial arts practice (i.e. using body contact techniques), has gained in popularity over time. This review explores the evidence for health benefits of "hard" martial arts practice within the adult population. A systematic electronic database search was conducted, and quality assessments applied the Effective Public Health Practice Project tool. Twenty-eight studies met the inclusion criteria, examining balance, cognitive function, muscular skeletal status, psychological, cardiovascular fitness, and metabolic effects. The majority of studies reported positive effects resulting from hard martial arts practice, showing some improvement and maintenance of balance, cognitive function and psychological health. Benefits may be obtained regardless of the age of practice commencement. However, quality of the evidence is affected by methodological weaknesses across the studies. "Hard" martial arts seem to have potential to improve balance and cognitive functions that decline with age, which can lead to poorer health outcomes among the elderly (e.g. cognitive decline, falls and fractures). Benefits should be further investigated with improved intervention studies, representative samples and longer follow-up periods in order to establish associations with morbidity and mortality in the long term.

ARTICLE HISTORY
Accepted 3 November 2017

KEYWORDS
Martial arts; adult; health; systematic review; exercise

Introduction

Physical inactivity is one of the major contributors to the global burden of disease, and the fourth leading risk factor for global mortality (Kohl et al., 2012). People who are physically inactive have a 20–30% increased risk of all-cause mortality (World Health Organization, 2015a). Physical activity participation also tends to decline in the adult population, being lowest in adults over 50 years of age (Guthold, Chatterji, Strong, Ono, & Morabia, 2008). In 2010, 23% of adults aged 18 years and over did not meet physical activity recommendations (Guthold et al., 2008; World Health Organization, 2015a). Furthermore, a recent systematic review reported adults spent between 5.3 and 9.4 hours in sedentary behaviors (sitting, watching TV and using computers) per day (Harvey, Chastin, & Skelton, 2015). These trends, coupled with an increasing ageing population, contribute towards increased risk and prevalence of chronic disease (Bamidis et al., 2014; World Health Organization, 2014).

There is also compelling evidence of multiple benefits of physical activity for health, in terms of: a reduction in the risk of premature death and developing cardiovascular disease; some types of cancer; diabetes; and musculoskeletal conditions such as osteoporosis and osteoarthritis (Brown, Bauman, Bull, & Burton, 2012; George et al., 2012; US Department of Health and Human Services, 2008). These benefits have been demonstrated in all age groups and in individuals with disabilities and chronic conditions (US Department of Health and Human Services, 2008). Physical activity is also positively associated with higher levels of well-being and improved mental health (George et al., 2012). Whilst benefits result from moderate intensity activities such as walking, vigorous activities (e.g. running) are also protective against all-cause mortality and might increase longevity in middle-aged and older adults (Gebel et al., 2015). Therefore, interventions that address lack of physical activity among the adult population are necessary to reduce the global burden of chronic diseases (Guthold et al., 2008; Hallal et al., 2012). Participation in organized sports (i.e. activities offered by a club or association) have been widely promoted as a means of increasing physical activity levels among the adult population (Australian Bureau of Statistics, 2012; Oja et al., 2015). National data has shown that one quarter of the US adult population participate in some form of organized sport or exercise (Ham, Kruger, & Tudor-Locke, 2009), whilst in European countries, sport participation has been estimated at 40% of the adult population (Khan et al., 2012). In Australia, two thirds (65%) of the adult population aged 15 years and over participated in physical activity for recreation, exercise or sport in 2011–12 and of these, a quarter (27%) undertook an organized activity (Australian Bureau of Statistics, 2012). These data show that organized activity participation contributes markedly to physical activity rates.

One organized activity that may offer promise is martial arts practice (Theeboom & Knop, 1999). Martial arts originated

CONTACT Lisa M. Barnett lisa.barnett@deakin.edu.au; Sandra Origua Rios drasankid@gmail.com School of Health and Social Development, Deakin University, Locked Bag 20000, Geelong VIC 3220 Australia
Supplemental data for this article can be accessed here.

with the purpose of fighting in conflict situations. In the modern context the concept includes systems of hand-to-hand fighting, self-defense and sport (Burke, Al-Adawi, Lee, & Audette, 2007). Since the 1950s the practice of Asian martial arts has become increasingly popular in the Western world (Burke et al., 2007; Theeboom & Knop, 1999; Yong Jae, Yu Kyoum, & Valacich, 2010). There has been a focus on several styles, such as kung fu, tai chi, karate, judo and taekwondo. Approximately 70 million people currently practice taekwondo worldwide and nearly a 100 million people are involved in competitive karate (World Karate Federation, 2014; Yong Jae et al., 2010).

The majority of martial arts can be distinguished by specific characteristics (Theeboom & Knop, 1999) and divided into two broad groups: "hard" or "external" and "soft" or "internal" martial arts. "Soft" or "internal" martial arts, such as tai chi, are characterized by smooth, relaxed movements often executed very slowly, aiming at the regulation of posture during the production of movements (Bell, 2008; Gorgy, Vercher, & Coyle, 2008; Theeboom & Knop, 1999). Hard martial arts are characterized by fast, vigorous and dynamic movements aimed at generating and transmitting the maximum force possible to the striking surface (Burke et al., 2007; Gorgy et al., 2008; Theeboom & Knop, 1999), relying on physical strength, speed and endurance (Bell, 2008). Hard martial arts complement the improvement of physical skills with mental and spiritual development (McCoy, 1997; Theeboom & Knop, 1999).

Hard martial arts, with moderate to vigorous training intensity (Fong & Ng, 2011; Milanez, Dantas, Christofaro, & Fernandes, 2012), have been increasingly used for cardiovascular fitness and physical health improvement during recent years in health clubs (Glass, Reeg, & Bierma, 2002; Yoshimuraa & Imamura, 2010). Furthermore, hard martial arts training seems to have positive effects on psychological health and well-being and may increase self-confidence and self-discipline (Glass et al., 2002; Toskovic, 2001). Nevertheless, evidence for the health benefits of hard martial arts training is limited. One systematic review of 11 studies examined effects on health, including studies involving elite competitors, results of which may not be generalizable to the broader population (Bu et al., 2010). Given the benefits that vigorous physical activity brings in mortality reduction and improved mental health in adults (Blake, Mo, Malik, & Thomas, 2009; Gebel et al., 2015), it is worthwhile exploring the potential health benefits of hard martial arts in this age group. The aim of this review is to answer the following question: What evidence is there for health benefits (psychological and physical) from the practice of hard martial arts in adults?

Methods

A systematic search, completed on September 23 2016, was conducted using the following databases: Academic Search Complete, AMED, CINAHL, EMBASE, Evidence Based Medicine, Cochrane Database of Systematic Reviews, EBM Reviews – Cochrane Central Register of Controlled Trials, Global Health, Health Source-Nursing/Academic Edition, MEDLINE Complete, PsycINFO, Psychology and Behavioral Sciences Collection, Scopus, SportDiscus and Web of Science. Searches included combinations of terms using various operators: a) Health, physiolog*, physical*, psycholog*, mental, well-being, benefit*, effect*, outcome*, b) kung fu, wushu, karate, taekwon*, muay thai, kickboxing, jujitsu, judo, kenpo, silat, martial arts, and c) adult*. An additional search strategy used the "Cited by" option in Scopus. One additional paper was suggested by a reviewer and was subsequently included.

Studies inclusion criteria were: 1) in English; 2) peer reviewed; 3) conducted in populations over the age of 18 years; 4) examined physical and/or psychological effects resulting from martial arts practice, with the potential to reduce risks of poorer health outcomes in the adult population; 5) included a "hard" martial art; and 6) were quantitative in design. Studies were excluded if they: were aimed at enhancing performance for competition or conducted under competition conditions; examined "soft" martial arts; reported solely on injuries resulting from the martial arts practice (Khan et al., 2012); were literature reviews, theses or dissertations.

A total of 1,843 records were identified via the searches outlined (Figure 1). After removal of duplicates, and articles not meeting the inclusion criteria after screening, a total of twenty-eight studies were included in the final review.

The Effective Public Health Practice Project quality assessment tool for quantitative studies was used to evaluate each study as either "strong", "moderate" or "weak" (Armijo-Olivo, Stiles, Hagen, Biondo, & Cummings, 2012) by two independent assessors. Any differences were discussed until agreement was reached. A third assessor was consulted to reach consensus on one assessment.

Results

Twenty eight studies met the inclusion criteria for this review, covering a period from 2001 to 2016 (Supplementary Table 1). Seven studies reported health effects from taekwondo practice, five from karate, and five from a combination of various martial arts. Four studies reported health effects of Soo Bahk do, three from judo, two from Ving tsun, one from Kung fu and one from Kickboxing. Twelve were intervention studies. Length of intervention ranged from one single training session or a few weeks (Brudnak, Dundero, & Van Hecke, 2002; Chyu et al., 2012; Cromwell, Meyers, Meyers, & Newton, 2007; Douris et al., 2015; Jansen & Dahmen-Zimmer, 2012; Lip, Fong, Ng, Liu, & Guo, 2015; Ouergui et al., 2014; Qasim, Ravenscroft, & Sproule, 2014; Toskovic, 2001; Yoshimuraa & Imamura, 2010) to 12 months (van Dijk, Lenssen, Leffers, Kingma, & Lodder, 2013c). Sixteen studies were observational, three case-control (Drozdzowska, Münzer, Adamczyk, & Pluskiewicz, 2011; Leong, Fu, Ng, & Tsang, 2011; Ulivieri et al., 2005) and 13 cross-sectional (Amtmann, Berry, & Spath, 2004; Andreoli et al., 2001; Douris et al., 2004, 2009, 2013; Fong et al., 2013; Kim, Seo, & Choi, 2014; Krampe, Smolders, & Doumas, 2014; McAnulty, McAnulty, Collier, Souza-Junior, & McBride, 2016; Muiños & Ballesteros, 2014, 2015; Perrin, Deviterne, Hugel, & Perrot, 2002; van der Zijden et al., 2012). Participants' years of training experience were not specified in four studies (Andreoli et al., 2001; Douris et al., 2015; Krampe et al., 2014; Ulivieri et al., 2005). However, in two of these studies participants had attained a black belt degree (Douris et al., 2015;

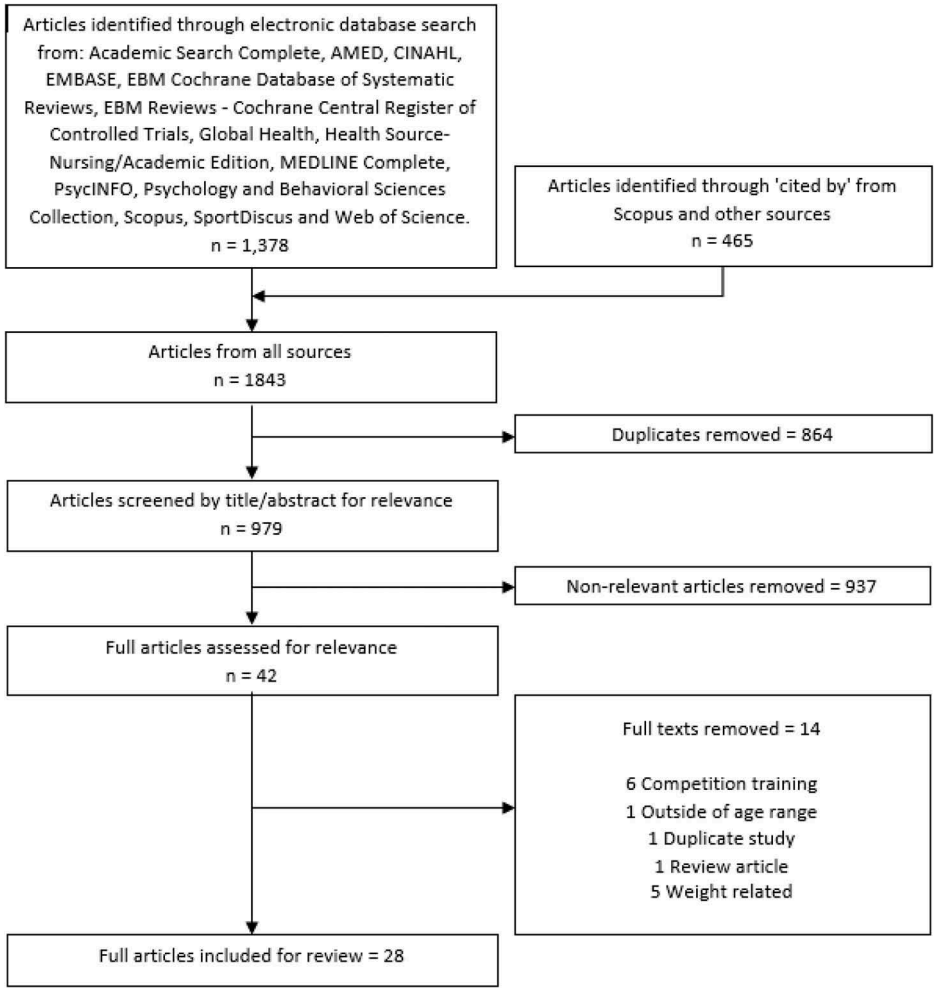

Figure 1. Flow chart showing stages of the systematic review search and study selection.

Krampe et al., 2014), and in one study regular attendance (at least two days per week) was specified (Douris et al., 2015). In 12 studies, participants had little or no martial arts training experience (Amtmann et al., 2004; Brudnak et al., 2002; Cromwell et al., 2007; Jansen & Dahmen-Zimmer, 2012; Leong et al., 2011; Lip et al., 2015; Ouergui et al., 2014; Qasim et al., 2014; Toskovic, 2001; Van Dijk, Huijts, & Lodder, 2013a; van Dijk et al., 2013c; Yoshimuraa & Imamura, 2010). Effects were examined on young (18–25 years) and middle-aged adults (26–60 years) in 19 studies (Amtmann et al., 2004; Andreoli et al., 2001; Brudnak et al., 2002; Chyu et al., 2012; Douris et al., 2004, 2015, 2009, 2013; Drozdzowska et al., 2011; Fong et al., 2013; Kim et al., 2014; Leong et al., 2011; McAnulty et al., 2016; Ouergui et al., 2014; Perrin et al., 2002; Qasim et al., 2014; Toskovic, 2001; Ulivieri et al., 2005; van der Zijden et al., 2012; Yoshimuraa & Imamura, 2010), 6 studies assessed effects on older adults (over 60 years of age) (Brudnak et al., 2002; Cromwell et al., 2007; Jansen & Dahmen-Zimmer, 2012; Lip et al., 2015; Van Dijk et al., 2013a, 2013c) and four studies made comparisons between different age groups (Krampe et al., 2014; McAnulty et al., 2016; Muiños & Ballesteros, 2014, 2015).

A range of effects on physical and mental health were assessed across the studies, with main findings summarized by type of health benefit (Table 1).

Two studies (7%) were assessed as having a "Strong" quality rating (Chyu et al., 2012; Jansen & Dahmen-Zimmer, 2012); six (21%) were rated as "Moderate" (Douris et al., 2013; Drozdzowska et al., 2011; Fong et al., 2013; Krampe et al., 2014; Lip et al., 2015; Toskovic, 2001) and 12 (71%) studies were rated as "weak" (Amtmann et al., 2004; Andreoli et al., 2001; Brudnak et al., 2002; Cromwell et al., 2007; Douris et al., 2004, 2015, 2009; Kim et al., 2014; Leong et al., 2011; McAnulty et al., 2016; Muiños & Ballesteros, 2014, 2015; Ouergui et al., 2014; Perrin et al., 2002; Qasim et al., 2014; Ulivieri et al., 2005; van der Zijden et al., 2012; Van Dijk et al., 2013a, 2013c; Yoshimuraa & Imamura, 2010). Lack of reported information in relation to the participants' recruitment process and blinding of assessors or participants were weaknesses for the majority of studies. Selection bias was also a weak component, particularly in intervention studies, due to the use of convenience rather than random sampling methods. Likewise, there were weaknesses in study design since most observational studies were cross-sectional. All studies except one (Qasim et al., 2014) controlled for relevant confounders such as age and gender. Most studies reported use of valid and reliable data collection methods.

Discussion

This review examined evidence for health benefits resulting from the practice of hard martial arts. Included studies assessed a

Table 1. Summary table of effects examined from the practice of hard martial arts.

Specific Health Benefit	Positive effect	No effect	Positive effects
Balance	(Brudnak et al., 2002; Cromwell et al., 2007; Fong et al., 2013; Krampe et al., 2014; Leong et al., 2011; Lip et al., 2015; Perrin et al., 2002; Douris et al., 2004; Van Dijk, Lenssen, Leffers, Kingma, & Lodder, 2013c)	–	9/9
Cognitive function	(P. Douris et al., 2015; Muiños and Ballesteros, 2015; Muiños & Ballesteros, 2014; Van Dijk, Huijts, & Lodder, 2013a)	(Jansen & Dahmen-Zimmer, 2012)	4/5
Muscular – Skeletal status	(Andreoli et al., 2001; Drozdzowska et al., 2011; Fong et al., 2013; (Douris et al., 2004)Ulivieri et al., 2005; van der Zijden et al., 2012)	(Chyu et al., 2012)	6/7
Psychological	(Chyu et al., 2012; Jansen & Dahmen-Zimmer, 2012; Lip et al., 2015; Qasim et al., 2014; Toskovic, 2001)	–	5/5
Cardiovascular fitness – metabolic effects	(Amtmann et al., 2004; Kim et al., 2014; P. C. Douris et al., 2009; P. C. Douris et al., 2013; McAnulty et al., 2016; Ouergui et al., 2014; Yoshimuraa & Imamura, 2010)	–	7/7

Positive effects means proportion of studies with a positive effect

wide variety of physical and psychological effects, showing positive results in young, middle-aged and older adults. Participants in the majority of intervention studies had no previous martial arts training, suggesting that benefits may be obtained regardless of age commencing hard martial arts practice.

Balance

Four intervention (Brudnak et al., 2002; Cromwell et al., 2007; Lip et al., 2015; van Dijk et al., 2013c) and five observational studies (Douris et al., 2004; Fong et al., 2013; Krampe et al., 2014; Leong et al., 2011; Perrin et al., 2002) assessed the effect of hard martial arts on balance and postural control. Three examined the effect of taekwondo training (Brudnak et al., 2002; Cromwell et al., 2007; van Dijk et al., 2013c) and another of Ving tsun (Lip et al., 2015) among older adults. Training programs included a short warm-up, stretching, taekwondo techniques, forms (e.g. poomsae, kata, hyung) and self-defense techniques. Two interventions found significant improvements in walking ability, flexibility, static and dynamic balance compared to the control groups (Cromwell et al., 2007; van Dijk et al., 2013c), and two reported improvement in balance (Brudnak et al., 2002; Lip et al., 2015).

Five observational studies comparing performance between martial art practitioners and untrained subjects of the same age reported positive findings in balance and postural control from hard martial arts practice. Greater balance ability was reported among taekwondo, judo, karate, Soo Bahk do and Ving tsun practitioners (Douris et al., 2004; Fong et al., 2013; Krampe et al., 2014; Leong et al., 2011; Perrin et al., 2002) compared to those who did other types of physical activity and sports such as dancing (Perrin et al., 2002), football, running, walking, swimming and cycling (Krampe et al., 2014), as well as those not involved in any type of physical activity (Douris et al., 2004; Leong et al., 2011).

Positive effects found of "hard" martial arts training on balance support a previous systematic review reporting improvement in postural control from karate training in professional athletes (Filingeri, Bianco, Zangla, Paoli, & Palma, 2012). However, athletes' specialty (i.e. whether they practiced kata or sparring) was not identified (Filingeri et al., 2012). Within the current review, taekwondo (Brudnak et al., 2002; Cromwell et al., 2007; van Dijk et al., 2013c) and Ving tsun training programs (Lip et al., 2015) were specifically designed for the participants age, having minimum sparring in their routines. All demonstrated balance benefits, suggesting that improvement in the somatosensory system may be obtained by learning basic techniques and moves only (Cromwell et al., 2007; Leong et al., 2011; van Dijk et al., 2013c). Balance is a complex function that integrates the processing of mechanical, sensory and motor stimuli. The organization of visual, proprioceptive (muscular response) and vestibular (balance and orientation) systems influences postural control (Leong et al., 2011). The martial arts studied combine kicking techniques, shifting weight between the lower limbs and these require participants to spend more time on single-leg support, improving both static and dynamic elements of balance (Cromwell et al., 2007). Sparring could be reduced or adapted in specific population groups considering participants' age and physical condition.

Cognitive functions

Effects on cognitive function were assessed in five studies, four with positive effects (Douris et al., 2015; Muiños & Ballesteros, 2014, 2015; Van Dijk et al., 2013a). Experienced Soo Bahk do participants demonstrated improvements in executive cognitive function (Douris et al., 2015), and taekwondo practice produced improvements in reaction time, motor time and processing speed (Van Dijk et al., 2013a). Karate and judo competitors were found to have faster reaction time to peripheral visual stimuli than non-athletes (Muiños & Ballesteros, 2014), and a delay in dynamic visual acuity decline (Muiños & Ballesteros, 2015). Within the latter study, participants were presented visual stimuli moving in three different trajectories (horizontal, vertical and diagonal) at different speeds. Older karate and judo athletes had better dynamic visual acuity than non-athletes of the same age (Muiños & Ballesteros, 2015). In contrast to these findings, no significant improvement in older adults cognitive function was found in a non-randomized trial from three different training programs (motor, cognitive, and karate trainings) (Jansen & Dahmen-Zimmer, 2012).

Evidence for the benefits of chronic physical activity on cognition in younger adults is scarce (Hillman, Erickson, & Kramer, 2008). In contrast, the relationship between physical activity and cognition has been studied in the elderly for several decades (Hillman et al., 2008). Epidemiological studies have found positive associations between physical activity and cognition, especially its potential role in delaying cognitive decline (Prakash, Voss, Erickson, & Kramer, 2015). Research has also reported positive effects on cognitive functions resulting from specific forms of physical activity (dancing, tai chi)

(Ballesteros, Kraft, Santana, & Tziraki, 2015). In contrast, there are very limited studies for effects on cognitive functions resulting from hard martial arts training (Van Dijk et al., 2013a). Findings from studies within this review show potential to prevent cognitive decline that occurs with age by training in hard martial arts. Effects were attributed to the complexity of the motor patterns practiced in the training programs, which require participants to change directions and demand memorization, concentration and attention (Van Dijk et al., 2013a), providing additional stimulation and increasing blood flow to brain areas involved in cognitive function (Douris et al., 2015). These findings highlight the importance of maintaining a physically active lifestyle to protect against cognitive decline and enhance brain neuroplasticity (Bamidis et al., 2014; Muiños & Ballesteros, 2014; Prakash et al., 2015).

Importantly, findings of this review support the increasing interest in identifying interventions for improving and maintaining cognitive function in the aging brain (Ballesteros et al., 2015), particularly within an ageing population. There appear to be few options to mitigate the progress of diseases such as dementia (Van Dijk et al., 2013a). Further investigation of the role of physical activity in general and particularly hard martial arts training in the prevention of cognitive decline is necessary.

Muscular and skeletal effects

Six observational studies (Andreoli et al., 2001; Douris et al., 2004; Drozdzowska et al., 2011; Fong et al., 2013; Ulivieri et al., 2005; van der Zijden et al., 2012) reported positive effects of "hard" martial arts training on muscular strength and/or skeletal status. One intervention did not show improvement in various body composition parameters of overweight women participating in short-term martial art exercise training (Chyu et al., 2012). Compared to controls, improvements in hand skeletal status measured by ultrasound (Drozdzowska et al., 2011), greater bone and hand grip strength (Fong et al., 2013), greater muscular strength and endurance, (Douris et al., 2004) and reduced hip impact (van der Zijden et al., 2012) were found in male karate (Drozdzowska et al., 2011), Ving tsun (Fong et al., 2013), male and female judo (van der Zijden et al., 2012) and male and female Soo Bahk do (Douris et al., 2004) practitioners respectively. Further observational studies demonstrated higher bone mineral density in female (Ulivieri et al., 2005) and male (Andreoli et al., 2001) karate, and male judo (Andreoli et al., 2001) athletes, compared to non-hard martial arts practitioners. Findings suggest that high-impact physical activities such as karate training may be effective at increasing bone mineral density and could be more effective than other alternatives such as calcium supplementation (Ulivieri et al., 2005). This is important in terms of the reduction of the risk of osteoporosis and fractures in the elderly population. However, the latter study reported effects on professional athletes who usually complement their martial arts training with other types of physical activity such as running or weight training in order to increase endurance and muscular strength (Yoshimuraa & Imamura, 2010). These additional activities may also have an effect on bone mineral density. Although there may be potential for "hard" martial arts to improve skeletal status, quality assessments within this review provided weak evidence. More controlled trials are needed to strengthen the evidence base.

Cardiovascular and metabolic effects

Seven studies reported a range of effects on the cardiovascular system and metabolic effects resulting from "hard" martial arts practice (Amtmann et al., 2004; Douris et al., 2009, 2013; Kim et al., 2014; McAnulty et al., 2016; Ouergui et al., 2014; Yoshimuraa & Imamura, 2010). Two interventions assessed effects of hard martial arts practice on cardiovascular fitness (Ouergui et al., 2014; Yoshimuraa & Imamura, 2010). One examined the effect of a basic karate exercise program in sedentary women with no previous experience in karate training (Yoshimuraa & Imamura, 2010). The other assessed a 5-week kickboxing training program in males (Ouergui et al., 2014). Both programs found positive effects. These studies (albeit limited due to methodological weaknesses) add to previous evidence found in observational studies (Imamura et al., 1999; Toskovic, Blessing, & Williford, 2002; Waggener, Boone, Kasper, & Waggener, 2007) by suggesting hard martial arts training as a potential alternative to improve cardiovascular fitness in sedentary individuals.

Two cross-sectional studies measured arterial stiffness in middle-aged Soo Bahk do practitioners (Douris et al., 2013) and in young and older Kung fu practitioners (McAnulty et al., 2016). Lower arterial stiffness was found among middle-aged adults who practiced Soo Bahk do compared to sedentary controls (Douris et al., 2013). This effect was not found among Kung fu practitioners, despite an improved physical fitness among the older participants (McAnulty et al., 2016). Other health effects found include: increases in heart rate in beginner judo participants (Amtmann et al., 2004); improved cardiorespiratory fitness in taekwondo practitioners (Kim et al., 2014) and improved protective response against oxidative stress in middle-aged adults who practice Soo Bahk do (Douris et al., 2009). Further research is required for the role of hard martial arts in improving cardiovascular health.

Psychological effects

Five studies reported positive psychological effects resulting from the practice of "hard" martial arts (Chyu et al., 2012; Jansen & Dahmen-Zimmer, 2012; Lip et al., 2015; Qasim et al., 2014; Toskovic, 2001). A dynamic taekwondo training session of 20 participants with no previous training in martial arts (age range 18–21 years) showed significant improvement in mood compared to a control group (Toskovic, 2001). Karate training showed positive effects on self-esteem, exercise self-efficacy and physical self-perception for individuals with visual impairment (Qasim et al., 2014) and improved emotional mental states of participants compared to a control group (Jansen & Dahmen-Zimmer, 2012). Martial arts exercise resulted in higher quality of life scores compared to controls (Chyu et al., 2012), whilst Ving tsun practitioners showed increases in balance confidence (Lip et al., 2015). All studies were conducted on diverse populations with no prior martial arts training. There was variety in age, gender and health conditions

such as visual impairment (Qasim et al., 2014) and overweight or obesity (Chyu et al., 2012). These findings support evidence that physical activity may have benefits on mood, which could help reduce risk of depression (Myrna-Bekas, Małgorzata, Stefaniak, & Kulmatycki, 2012; Toskovic, 2001). Consistent with our results, a systematic review of physical activity interventions also found that exercise may help reduce depressive symptoms among older adults (Blake et al., 2009). A recent study found positive effects on mood from regular participation in different types of physical activity regardless the type and duration of training (Myrna-Bekas et al., 2012). However, weaknesses in two of the studies in the current review (Qasim et al., 2014; Toskovic, 2001) affect the strength of the evidence and temper our conclusions on the potential benefits of the training programs for mental health.

Injury risk

Although reports on injuries were not within the focus of this review, it is important to note that injuries can be an adverse health outcome from sports practice, including "hard" martial arts (Finch & Cassell, 2006; Tsang, Kohn, Chow, & Singh, 2008). There are extensive reports on injury rates among different martial arts, mostly in competitions, where the majority of injuries are mild (Lystad, Pollard, & Graham, 2009). At the community level, 172 presentations due to combat sports injury were reported in an Irish emergency department over a six-month period, being the lowest figure (4.2%) among all the sports surveyed (Falvey et al., 2009). A Canadian study reported 920 emergency presentations due to injuries resulting from martial arts practice between 1993 and 2006 (McPherson & Pickett, 2010). Three quarters (74%) were mild injuries, with severe injuries mostly involving misuse of weapons (McPherson & Pickett, 2010). These data suggest that compared with other sports, martial arts examined in this review may be considered relatively safe (Tsang et al., 2008).

Only one intervention in this review reported incidence of injuries, mostly minor, resulting from martial arts training (Van Dijk, Leffers, & Lodder, 2013b). The majority of studies included in this review showed benefits resulting from practicing basic techniques (punches and kicks), moves in different directions and fixed patterns (e.g. "kata" or "poomsae"). Sparring and self-defense were used in a few interventions as a small part of training programs. In vulnerable populations such as the elderly, sparring practice could be reduced to minimize injury risk, and it can also be suppressed (Cromwell et al., 2007; van Dijk et al., 2013c). Training programs should be designed according to the age and physical condition of the participants and emphasize repetition of basic techniques and forms. Since these forms of training do not involve full contact, risk of injury is lower than for sparring. Given the potential benefits, hard martial arts with scarce or adapted sparring with minimal contact may be encouraged among adult populations at any age.

Strengths and limitations

This study has several limitations. Inclusion of literature written in languages other than English may have helped identify a greater number of studies conducted on hard martial arts practice. Second, research on these disciplines has predominantly been conducted on athletes and aimed at improving performance in competition (Bu et al., 2010), limiting the generalizability of results. Research on benefits of hard martial arts to physical and mental health and wellbeing in non-competitive contexts has slowly emerged during recent decades (Glass et al., 2002; Wilkinson, 1996). Third, despite the classification of martial arts as "soft" or "hard" styles used in this review, there are blurred lines between the styles. It has been argued that most martial arts combine elements of both styles (Bell, 2008; Theeboom & Knop, 1999). This diversity makes the study of health benefits per martial art more difficult (Bu et al., 2010). Finally, due to the variety of study designs and effects reported, it was not possible to conduct a meta-analysis and estimate the effect sizes of martial arts training.

Nevertheless, a strength of this review is that it examined "hard" martial arts that share similarities in techniques and moves. Inclusion and exclusion criteria allowed identification of studies conducted in populations who were not involved in competition, and therefore the results may be more applicable to the general population.

Conclusion and recommendations

Within this review, hard martial arts have been shown to have various effects on multiple aspects of health. Positive effects were reported among young, middle-aged and older adults who were not previously involved in martial arts training. This suggests that adults may benefit from hard martial arts practice regardless of age of commencement of practice. It is also noteworthy that there was a diversity of hard martial arts being investigated for their health benefits. Apart from traditional Asian martial arts such as judo, karate or taekwondo, other hard martial arts (e.g. Ving tsun, Soo Bahk do) are also gaining attention in the literature. Given the variety of martial arts and effects examined, and a lower rate of severe injuries compared to other sports, hard martial arts could be used to engage the adult population in sports and physical activity in non-competitive contexts. Particularly, the martial arts examined in this review may be a useful source of physical activity as they emphasize techniques mostly using arms and legs and limited use of weapons. All these aspects are important considering low levels of physical activity and sports participation among the adult population and negative effects that physical inactivity has on health. An interesting finding in this review were the reports of positive effects for physical and mental health of older adults as a result of hard martial arts practice. This shows an increasing interest in finding interventions to help improve and maintain functions that decline with age and have been associated with poorer health outcomes in the elderly. A challenge for public health is to reduce the burden of chronic disease due to physical inactivity among the general population (Guthold et al., 2008) and live longer, healthier lives.

However, weaknesses in methodological aspects across the studies affect the strength of the evidence. Small sample sizes and convenience sampling methods affect the representativeness of the samples and the generalizability of the results to a

broader population. There were also blinding difficulties as outcome assessors in some interventions were involved in providing the intervention (Qasim et al., 2014), or the allocation to intervention and comparison groups was not random. Most interventions had a short duration (10 to 12 weeks) and high dropout rates. Moreover, some interventions had low adherence among their participants. As a result, the evidence for health benefits of hard martial arts remains weak. This is consistent with previous work on health benefits of kung fu, where nine observational studies all presented similar design quality weaknesses (Tsang et al., 2008). A further review found only a small proportion of studies examining health effects resulting from the practice of judo (six studies) taekwondo (one study), karate (three studies) and kung fu (one study) (Bu et al., 2010). Studies included in the latter review mostly aimed at improving performance of competitors in these martial arts. Therefore, applicability of results to the general population is limited. Further research on the effects reported in this review should be conducted with improved study designs, representative samples and longer follow-up periods to establish what frequency and intensity can elicit more benefits. It is also necessary to ascertain associations between the effects reported and reductions in the risk of morbidity and mortality in the long-term.

In summary, several effects on health resulting from hard martial arts training have been examined across the studies included in this review. Hard martial arts training appears to help balance and postural control, and has positive effects on cognitive function and psychological health. This is important because the studies included in this review showed improvement in balance and cognitive function among middle-aged and older adults with no previous experience in martial arts training, which suggests that benefits can be obtained regardless of the age of commencement of practice. Stronger evidence on the potential health benefits of martial arts for adult populations is needed.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Jennifer Marks http://orcid.org/0000-0002-4551-7332
Isaac Estevan http://orcid.org/0000-0003-3748-2288

References

Amtmann, J., Berry, S., & Spath, W. K. (2004). Effects of a beginning judo class on heart rate. *Intermountain Journal of Sciences*, *10*(1–4), 20–24.

Andreoli, A., Monteleone, M., Van Loan, M., Promenzio, L., Tarantino, U., & De Lorenzo, A. (2001). Effects of different sports on bone density and muscle mass in highly trained athletes. *Medicine And Science In Sports And Exercise*, *33*(4), 507–511. doi:10.1097/00005768-200104000-00001

Armijo-Olivo, S., Stiles, C. R., Hagen, N. A., Biondo, P. D., & Cummings, G. G. (2012). Assessment of study quality for systematic reviews: A comparison of the Cochrane Collaboration Risk of Bias Tool and the Effective Public Health Practice Project Quality Assessment Tool: methodological research. *Journal of Evaluation in Clinical Practice*, *18*(1), 12–18. doi:10.1111/j.1365-2753.2010.01516.x

Australian Bureau of Statistics. (2012). Sport and recreation: A statistical overview. Australia 4156.0). Canberra, Australia. Retrived from http://www.ausstats.abs.gov.au/ausstats/subscriber.nsf/0/6E28777ED2896A2BCA257AD9000E2FC5/$File/41560_2012.pdf

Ballesteros, S., Kraft, E., Santana, S., & Tziraki, C. (2015). Maintaining older brain functionality: A targeted review. *Neuroscience & Biobehavioral Reviews*, *55*, 453–477. doi:10.1016/j.neubiorev.2015.06.008

Bamidis, P. D., Vivas, A. B., Styliadis, C., Frantzidis, C., Klados, M., Schlee, W., … Papageorgiou, S. G. (2014). A review of physical and cognitive interventions in aging. *Neuroscience & Biobehavioral Reviews*, *44*, 206–220. doi:10.1016/j.neubiorev.2014.03.019

Bell, C. C. (2008). Asian martial arts and resiliency. *Ethnicity and Inequalities in Health and Social Care*, *1*(2), 11–17. doi:10.1108/17570980200800016

Blake, H., Mo, P., Malik, S., & Thomas, S. (2009). How effective are physical activity interventions for alleviating depressive symptoms in older people? A systematic review. *Clinical Rehabilitation*, *23*(10), 873–887. doi:10.1177/0269215509337449

Brown, W., Bauman, A., Bull, F., & Burton, N. (2012). Development of Evidence-based Physical Activity Recommendations for Adults (18-24 years) Report prepared for the Australian Government Department of Health. Retreived from http://www.health.gov.au/internet/main/publishing.nsf/content/health-pubhlth-strateg-phys-act-guidelines

Brudnak, M. A., Dundero, D., & Van Hecke, F. M. (2002). Are the `hard' martial arts, such as the Korean martial art, TaeKwon-Do, of benefit to senior citizens? *Medical Hypotheses*, *59*(4), 485–491. doi:10.1016/S0306-9877(02)00203-7

Bu, B., Haijun, H., Yong, L., Chaohui, Z., Xiaoyuan, Y., & Singh, M. F. (2010). Effects of martial arts on health status: A systematic review. *Journal Of Evidence-Based Medicine*, *3*(4), 205–219. doi:10.1111/j.1756-5391.2010.01107.x

Burke, D. T., Al-Adawi, S., Lee, Y. T., & Audette, J. (2007). Martial arts as sport and therapy. *Journal of Sports Medicine and Physical Fitness*, *47*(1), 96–102.

Chyu, M.-C., Dagda, R. Y., Doctolero, S., Chaung, E., Von Bergen, V., Zhang, Y., … Shen, C.-L. (2012). Effect of martial arts exercise on body composition, bone biomarkers, and quality of life in overweight premenopausal women. *Medicine And Science In Sports And Exercise*, *44*, 270.

Cromwell, R. L., Meyers, P. M., Meyers, P. E., & Newton, R. A. (2007). Tae Kwon Do: An effective exercise for improving balance and walking ability in older adults. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *62*(6), 641–646. doi:10.1093/gerona/62.6.641

Douris, P., Chinan, A., Gomez, M., Aw, A., Steffens, D., & Weiss, S. (2004). Fitness levels of middle aged martial art practitioners. *British Journal of Sports Medicine*, *38*(2), 143–147. doi:10.1136/bjsm.2002.001768

Douris, P., Douris, C., Balder, N., LaCasse, M., Rand, A., Tarapore, F., … Handrakis, J. (2015). Martial art training and cognitive performance in middle-aged adults. *Journal of Human Kinetics*, *47*(1), 277–283. doi:10.1515/hukin-2015-0083

Douris, P. C., Elokda, A. S., Handrakis, J. P., Principal, S., Rondo, E., Bovell, J., … Zimmerman, T. (2009). Martial art training enhances the glutathione antioxidant system in middle-aged adults. *Journal Of Strength And Conditioning Research/National Strength & Conditioning Association*, *23*(5), 1518–1523. doi:10.1519/JSC.0b013e3181b339ac

Douris, P. C., Ingenito, T., Piccirillo, B., Herbst, M., Petrizzo, J., Cherian, V., … Jung, M.-K. (2013). Martial arts training attenuates arterial stiffness in middle aged adults. *Asian Journal Of Sports Medicine*, *4*(3), 201–207. doi:10.5812/asjsm.34259

Drozdzowska, B., Münzer, U., Adamczyk, P., & Pluskiewicz, W. (2011). Skeletal Status Assessed by Quantitative Ultrasound at the Hand Phalanges in Karate Training Males. *Ultrasound in Medicine & Biology*, *37*(2), 214–219. doi:10.1016/j.ultrasmedbio.2010.10.023

Falvey, E. C., Eustace, J., Whelan, B., Molloy, M. S., Cusack, S. P., Shanahan, F., & Molloy, M. G. (2009). Sport and recreation-related injuries and fracture occurrence among emergency department attendees: Implications for exercise prescription and injury prevention. *Emergency Medicine Journal*, *26*(8), 590–595. doi:10.1136/emj.2008.062315

Filingeri, D., Bianco, A., Zangla, D., Paoli, A., & Palma, A. (2012). Is karate effective in improving postural control? *Archives of Budo*, *8*(4), 203–206. doi:10.12659/AOB.883521

Finch, C., & Cassell, E. (2006). The public health impact of injury during sport and active recreation. *Journal of Science and Medicine in Sport*, *9*(6), 490–497. doi:10.1016/j.jsams.2006.03.002

Fong, S. S. M., Guo, X., Cheung, A. P. M., Jo, A. T. L., Lui, G. K. W., Mo, D. K. C., … Tsang, W. W. N. (2013). Elder Chinese martial art practitioners have higher radial bone strength, hand-grip strength, and better standing balance control. *ISRN Rehabilitation*, 1–6. doi:10.1155/2013/185090

Fong, S. S. M., & Ng, G. Y. F. (2011). Does Taekwondo training improve physical fitness? *Physical Therapy in Sport*, *12*(2), 100–106. doi:10.1016/j.ptsp.2010.07.001

Gebel, K., Ding, D., Chey, T., Stamatakis, E., Brown, W. J., & Bauman, A. E. (2015). EFfect of moderate to vigorous physical activity on all-cause mortality in middle-aged and older australians. *JAMA Internal Medicine*, *175*, 970. doi:10.1001/jamainternmed.2015.0541

George, E. S., Kolt, G. S., Duncan, M. J., Caperchione, C. M., Mummery, W. K., Vandelanotte, C., … Noakes, M. (2012). A review of the effectiveness of physical activity interventions for adult males. *Sports Medicine(4)*, *42*, 281–300. doi:10.2165/11597220-000000000-00000

Glass, S. C., Reeg, E. A., & Bierma, J. L. (2002). Caloric cost of martial arts training in novice participants. *Journal of Exercise Physiology Online*, *5* (4), 29–34.

Gorgy, O., Vercher, J.-L., & Coyle, T. (2008). How does practise of internal Chinese martial arts influence postural reaction control? *Journal of Sports Sciences*, *26*(6), 629–642. doi:10.1080/02640410701670401

Guthold, R., Chatterji, S., Strong, K. L., Ono, T., & Morabia, A. (2008). Worldwide variability in physical inactivity. A 51-country survey. *American Journal of Preventive Medicine*, *34*(6), 486–494. doi:10.1016/j.amepre.2008.02.013

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: Surveillance progress, pitfalls, and prospects. *Lancet (British Edition)*, *379*(9838), 247–257.

Ham, S. A., Kruger, J., & Tudor-Locke, C. (2009). Participation by US adults in sports, exercise, and recreational physical activities. *Journal of Physical Activity & Health*, *6*(1), 6–14. doi:10.1123/jpah.6.1.6

Harvey, J. A., Chastin, S. F. M., & Skelton, D. A. (2015). How sedentary are older people? A systematic review of the amount of sedentary behavior. *Journal of Aging & Physical Activity*, *23*(3), 471–487. doi:10.1123/japa.2014-0164

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature Reviews Neuroscience*, *9*, 58–65. doi:10.1038/nm2298

Imamura, H., Yoshimura, Y., Nishimura, S., Nakazawa, A. T., Nishimura, C., & Shirota, T. (1999). Oxygen uptake, heart rate, and blood lactate responses during and following karate training. *Medicine & Science in Sports & Exercise*, *31*(2), 342–347. doi:10.1097/00005768-199902000-00019

Jansen, P., & Dahmen-Zimmer, K. (2012). Effects of cognitive, motor, and karate training on cognitive functioning and emotional well-being of elderly people. *Frontiers In Psychology*, *3*, 40. doi:10.3389/fpsyg.2012.00040

Khan, K. M., Thompson, A. M., Blair, S. N., Sallis, J. F., Powell, K. E., Bull, F. C., & Bauman, A. E. (2012). Sport and exercise as contributors to the health of nations. *The Lancet*, *380*(9836), 59–64. doi:10.1016/S0140-6736(12)60865-4

Kim, D.-Y., Seo, B.-D., & Choi, P.-A. (2014). Influence of taekwondo as security martial arts training on anaerobic threshold, cardiorespiratory fitness, and blood lactate recovery. *Journal Of Physical Therapy Science*, *26*(4), 471–474. doi:10.1589/jpts.26.471

Kohl, H. W., 3rd, Craig, C. L., Lambert, E. V., Inoue, S., Alkandari, J. R., Leetongin, G., & Kahlmeier, S. (2012). The pandemic of physical inactivity: Global action for public health. *The Lancet*, *380*(9838), 294–305. doi:10.1016/S0140-6736(12)60898-8

Krampe, R. T., Smolders, C., & Doumas, M. (2014). Leisure sports and postural control: Can a black belt protect your balance from aging? *Psychology And Aging*, *29*(1), 95–102. doi:10.1037/a0035501

Leong, H.-T., Fu, S. N., Ng, G. Y. F., & Tsang, W. W. N. (2011). Low-level Taekwondo practitioners have better somatosensory organisation in standing balance than sedentary people. *European Journal Of Applied Physiology*, *111*(8), 1787–1793. doi:10.1007/s00421-010-1798-7

Lip, R. W. T., Fong, S. S. M., Ng, S. S. M., Liu, K. P. Y., & Guo, X. (2015). Effects of Ving Tsun Chinese martial art training on musculoskeletal health, balance performance, and self-efficacy in community-dwelling older adults. *Journal Of Physical Therapy Science*, *27*(3), 667–672. doi:10.1589/jpts.27.667

Lystad, R. P., Pollard, H., & Graham, P. L. (2009). Epidemiology of injuries in competition taekwondo: A meta-analysis of observational studies. *Journal of Science and Medicine in Sport*, *12*(6), 614–621. doi:10.1016/j.jsams.2008.09.013

McAnulty, S., McAnulty, L., Collier, S., Souza-Junior, T. P., & McBride, J. (2016). Tai Chi and Kung-Fu practice maintains physical performance but not vascular health in young versus old participants. *The Physician and Sportsmedicine*, *44* (2), 184–189. doi:10.1080/00913847.2016.1158623

McCoy, D. (1997). Chapter 20: martial arts. In P. Mosely, R. Cashman, J. O'Hara, & H. Weatherburn (Eds.), *Sporting Immigrants: Sport and Ethnicity in Australia* (pp. 238–250). Walla Walla Press.

McPherson, M., & Pickett, W. (2010). Characteristics of martial art injuries in a defined Canadian population: A descriptive epidemiological study. *BMC Public Health*, *10*, 795–801. doi:10.1186/1471-2458-10-795

Milanez, V. F., Dantas, J. L., Christofaro, D. G. D., & Fernandes, R. A. (2012). Resposta da frequência cardíaca durante sessão de treinamento de karatê. *Revista Brasileira de Medicina do Esporte*, *18*(1), 42–45. doi:10.1590/S1517-86922012000100009

Muiños, M., & Ballesteros, S. (2014). Peripheral vision and perceptual asymmetries in young and older martial arts athletes and nonathletes. *Attention, Perception & Psychophysics*, *76*(8), 2465–2476. doi:10.3758/s13414-014-0719-y

Muiños, M., & Ballesteros, S. (2015). Sports can protect dynamic visual acuity from aging: A study with young and older judo and karate martial arts athletes. *Attention, Perception, & Psychophysics*, *77*(6), 2061–2073. doi:10.3758/s13414-015-0901-x

Myrna-Bekas, R., Kałwa, M., Stefaniak, T., & Kulmatycki, L. (2012). Mood changes in individuals who regularly participate in various forms of physical activity. *Human Movement*, *13*(2), 170–177. doi:10.2478/v10038-012-0019-0

Oja, P., Titze, S., Kokko, S., Kujala, U. M., Heinonen, A., Kelly, P., … Foster, C. (2015). Health benefits of different sport disciplines for adults: Systematic review of observational and intervention studies with meta-analysis. *British Journal of Sports Medicine*, *49*(7), 434–440. doi:10.1136/bjsports-2014-093885

Ouergui, I., Hssin, N., Haddad, M., Padulo, J., Franchini, E., Gmada, N., & Bouhlel, E. (2014). The effects of five weeks of kickboxing training on physical fitness. *Muscles, Ligaments & Tendons Journal (MLTJ)*, *108*, 106–113.

Perrin, P., Deviterne, D., Hugel, F., & Perrot, C. (2002). Judo, better than dance, develops sensorimotor adaptabilities involved in balance control. *Gait & Posture*, *15*(2), 187–194. doi:10.1016/S0966-6362(01)00149-7

Prakash, R. S., Voss, M. W., Erickson, K. I., & Kramer, A. F. (2015). Physical activity and cognitive vitality. *Annu Rev Psychol*, *66*, 769–797. doi:10.1146/annurev-psych-010814-015249

Qasim, S., Ravenscroft, J., & Sproule, J. (2014). The effect of Karate practice on self-esteem in young adults with visual impairment: A case study. [Conference Paper]. *Australian Journal of Educational and Developmental Psychology*, *14*(SPEC. ISS.), 167–185.

Theeboom, M., & Knop, P. D. (1999). Asian martial arts and approaches of instruction in physical education. *European Journal of Physical Education*, *4*(2), 146–161. doi:10.1080/1740898990040204

Toskovic, N. N. (2001). Alterations in selected measures of mood with a single bout of dynamic Taekwondo exercise in college-age students. *Perceptual and Motor Skills*, *92*(3_suppl), 1031–1038. doi:10.2466/pms.2001.92.3c.1031

Toskovic, N. N., Blessing, D., & Williford, H. N. (2002). The effect of experience and gender on cardiovascular and metabolic responses with dynamic Tae kwon do exercise. *Journal of Strength and Conditioning Research*, *16*(2), 278–285. doi:10.1519/1533-4287(2002)016<0278:TEOEAG>2.0.CO;2

Tsang, T. W. M., Kohn, M., Chow, C. M., & Singh, M. F. (2008). Health benefits of Kung Fu: A systematic review. *Journal of Sports Sciences*, *26*(12), 1249–1267. doi:10.1080/02640410802155146

Ulivieri, F. M., Piodi, L. P., Marinelli, D., Cremonesi, G., Miserocchi, G., Verdoia, C., … Taioli, E. (2005). High-intensity exercise in female athletes: Effects on bone mass and body composition. *Journal of Orthopaedics and Traumatology*, *6*(1), 30–35. doi:10.1007/s10195-005-0077-6

US Department of Health and Human Services. (2008). Physical activity guidelines for Americans. Retrieved from https://health.gov/paguidelines/guidelines/

van der Zijden, A. M., Groen, B. E., Tanck, E., Nienhuis, B., Verdonschot, N., & Weerdesteyn, V. (2012). Can martial arts techniques reduce fall severity? An

in vivo study of femoral loading configurations in sideways falls. *Journal of Biomechanics*, *45*(9), 1650–1655. doi:10.1016/j.jbiomech.2012.03.024

Van Dijk, G. P., Huijts, M., & Lodder, J. (2013a). Cognition improvement in Taekwondo novices over 40. Results from the SEKWONDO Study. *Frontiers in Aging Neuroscience*, *5*, 74.

Van Dijk, G. P., Leffers, P., & Lodder, J. (2013b). Feasibility, safety and subjective experience of a one-year WTF-Taekwondo training course for middle-aged volunteers: The Sekwondo study. *Gazzetta Medica Italiana Archivio per Le Scienze Mediche*, *172*(6), 433–441.

van Dijk, G. P., Lenssen, A. F., Leffers, P., Kingma, H., & Lodder, J. (2013c). Taekwondo training improves balance in volunteers over 40. *Frontiers in Aging Neuroscience*, *5*. doi:10.3389/fnagi.2013.00010

Waggener, G. T., Boone, T., Kasper, M., & Waggener, A. T. (2007). Cardiovascular responses during karate exercise regimen and treadmill exercise at approximately 70% HR intensity. *Journal of Exercise Physiology Online*, *10*(4), 29–34.

Wilkinson, L. K. (1996). The martial arts: A mental health intervention? *Journal of the American Psychiatric Nurses Association*, *2*(6), 202–206. doi:10.1177/107839039600200604

World Health Organization. (2014). Facts about ageing. Retrieved from http://www.who.int/ageing/about/facts/en/

World Health Organization. (2015a). Prevalence of insufficient physical activity. Retrieved from http://www.who.int/gho/ncd/risk_factors/physical_activity_text/en/.

World Karate Federation. (2014). World Karate Federation: The book. Retrieved from http://www.wkf.net/thebook/.

Yong Jae, K., Yu Kyoum, K., & Valacich, J. (2010). Martial arts participation: Consumer motivation. *International Journal of Sports Marketing & Sponsorship*, *11*(2), 105–123.

Yoshimuraa, Y., & Imamura, H. (2010). Effects of basic karate exercises on maximal oxygen uptake in sedentary collegiate women. *Journal of Health Science*, *56*(6), 721–726. doi:10.1248/jhs.56.721