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Title: Martial arts, combat sports, and mental health in adults : A systematic review

Year: 2024

Version: Published version

Psychology of Sport & Exercise 70 (2024) 102556

Contents lists available at ScienceDirect

Psychology of Sport & Exercise

journal homepage: www.elsevier.com/locate/psychsport

Review

Martial arts, combat sports, and mental health in adults: A systematic review

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ARTICLE INFO

Keywords:
Exercise
Fighting
Self
Emotion
Cognition
Well-being

ABSTRACT

Martial arts (MA) and combat sports (CS) are physical activities that may be associated with health-related outcomes. The aim of this systematic review was to synthesize and evaluate the available evidence on the relationship between MA and CS training and mental health of adult practitioners (≥18 years). CochraneLibrary, EBSCOhost, Web-of-Science, and Scopus databases were searched up to September 2022 for measures of self-related constructs, ill-being and well-being, cognition and brain structure/function, in adult MA/CS practitioners. Seventy cross-sectional and two longitudinal studies were retained and submitted to risk of bias assessments through an adapted version of the Cochrane Collaboration's Tool. Associations between MA/CS practice and self-related constructs were inconclusive for both consistency and strength of evidence. Limited evidence of significant associations emerged for sub-domains of ill-being (i.e., externalizing and internalizing emotion regulation), and well-being. In regard to cognitive and brain structural/functional variables, evidence of positive association with MA/CS practice was consistent with respect to perceptual and inhibition abilities but limited with respect to attention and memory. Evidence on negative associations of boxing with changes of brain structure integrity due to concussions was also inconclusive. Functional imaging techniques could shed light onto brain activation mechanisms underlying complex cognitive performance. In relation to moderators, mixed results were found for activity exposure, expertise, level of competitive engagement (which often covary with the length of training) and sex and type of MA/CS. The MA/CS' multifaceted nature may produce different, sometimes conflicting outcomes on mental health. Studies on MA/CS represent a flourishing research area needing extensive improvement in theoretical and practical approaches.

The field of physical activity and sport covers a wide range of disciplines, including multi-faceted practices like fighting arts (Donohue & Taylor, 1994) which, beyond combative aspects, often include the development of discipline and other personal qualities. In this sense, they resemble what Vergeer et al. (2021) have called holistic movement practices, and may be particularly advantageous for mental health outcomes.

1. Mental health

Mental health plays an essential role in many individual and social aspects across the lifespan (Prince et al., 2007; World Health Organisation, 2021). Framed within a wide variety of theories, mental health has been a contested concept for decades. Recently, 34 different models were identified and grouped into five broader and interconnected categories, with the biological and psychological approaches and the social, consumer and cultural approaches representing the most and least

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https://doi.org/10.1016/j.psychsport.2023.102556
Received 17 January 2023; Received in revised form 15 September 2023; Accepted 29 October 2023
Available online 8 November 2023

diversified theories, respectively (Richter & Dixon, 2022). Therefore, incorporating both psychological and biological data, mental health will be operationalised as a set of comprehensive and integrated outcomes such as self-related constructs (e.g., self-esteem, body image), ill-being (i.e., negatively framed emotions and emotional-related behavioural disorders such as depression, anxiety), well-being (i.e., positively framed states and skills such as emotional intelligence, copying, life satisfaction) and cognition (with underlying brain health mechanisms) (American Psychiatric Association, 2013; Lubans et al., 2016; World Health Organisation, 2021). Whilst people with positive self-esteem and a healthy body image are generally more resilient to stress and may be better able to cope with life's challenges, individuals with cognitive impairments and those socially isolated may be at higher risk for developing mental health problems, negative thought patterns and unhealthy behaviours (American Psychiatric Association, 2013; World Health Organisation, 2021). Mental disorders affect millions of people worldwide and account for approximately 10 % of the global burden of disease (World Health Organisation, 2018; 2021). Moreover, mental disorders frequently lead individuals and families into poverty, and produce disproportionately higher rates of mortality (Allen et al., 2014; Bratman et al., 2019; World Health Organisation, 2021).

2. Physical activity

Connections between physical activity (i.e., any bodily movement produced by skeletal muscles that requires energy expenditure, thus including any modality of movement at any intensity) and mental health have been well documented (Biddle et al., 2019; Cortis et al., 2017; World Health Organisation, 2022) with clear interlinks between physical and mental health and quality of life (Biddle et al., 2021; Ciaccioni et al., 2022). Compared to inactive people, individuals who perform greater amounts of moderate-to-vigorous physical activity are likely to experience improvements in anxiety, stress, depression, self-esteem, mood, and cognition (Biddle et al., 2021), and to have lower risks of developing cognitive impairment and dementia (US Department of Health and Human Services, 2018). Whilst in youth strong evidence for a causal association between physical activity and mental health emerges for cognitive functioning, in older adults exercise is particularly effective in reducing depressive symptoms (Biddle et al., 2019; Catalan-Matamoros et al., 2016). Still the complicated and interconnected mechanisms underlying the relationships between physical activity and mental health remain unclear (Rose & Soundy, 2020; Taylor & Faulkner, 2008). Second, there is a need to investigate whether these associations are consistent across dissimilar socio-economic and cultural contexts (Pesce et al., 2021; White et al., 2017). Third, more research is needed to explore the role of different types and characteristics of exercise (e.g., sport vs leisure, low vs high intensity, multicomponent vs single-component, supervised versus self-initiated) in promoting mental health (Rebar & Taylor, 2017; Fessel et al., 2017; Vella et al., 2023).

3. Martial arts and combat sports

Martial arts (MA) and combat sports (CS) are athletic activities with specific rules involving fighting through striking, kicking and/or throwing, where the participants try to physically overcome the opponent while avoiding being overcome (Barreira, 2017; Fuller, 1988; Moore et al., 2020; Valdés-Badilla et al., 2021, 2022). Often overlapping and incorporating similar elements many types of MA and CS exist, including: 1) "Hard" (e.g., karate and boxing, focusing on striking or hitting an opponent) vs. "soft" (e.g., aikido, using an opponent's energy against them) MA; 2) "Traditional" (e.g., kung fu, practiced for hundreds or even thousands of years usually adhering to moral principles and codes of conduct, and also drawing ideas from philosophical, religious or educational teachings) vs. "modern" (e.g., mixed martial arts-MMA developed more recently, often as a combination of various traditional MA) practices; 3) "Internal" (e.g., tai chi, developing the body internal energy) vs. "external" (e.g., taekwondo, placing greater emphasis on physical strength, speed, and agility) categories; and 4) "Sport" (e.g., Olympic wrestling and judo, adapted for competitive disciplines) vs. "combat" (e.g., krav maga and jeet kune do, focusing on real-world self-defence situations) styles (Buckler, 2016; Donohue & Taylor, 1994; Martínková & Parry, 2016; Miller et al., 2022; Rossi et al., 2022; Tong, 2022). Although combat actions might suffer a negative image of violence, MA unite aesthetic and philosophical aspects, which might overlap with some movement-based holistic mind-body disciplines such as yoga and qigong associated with numerous psychosocial benefits, including breath control and relaxation, discipline, respect, self-esteem, and mind-body coordination (Park et al., 2020; Vergeer & Biddle, 2021; Woodward, 2009). From seminal works to more recent scientific evidence and clinical case reports MA are described as a useful instrument for effective management of physical and mental energy, as well as psychotherapeutic applications (Bu et al., 2010; Ciaccioni et al., 2019; Fuller, 1988; Origua Rios et al., 2017; Seitz et al., 1990; Vergeer & Biddle, 2021; Weiser et al., 1995; Woodward, 2009). A recent meta-analysis reported that MA engender positive effects on mental health outcomes and supported them as efficacious sports-based interventions for improving well-being and reducing symptoms associated with internalizing mental health problems such as anxiety and depression (Moore et al., 2020). While previous reviews on MA and CS have focused on intervention studies (Moore et al., 2020; Origua Rios et al., 2017; Valdés-Badilla et al., 2021, 2022), a significant number of cross-sectional and longitudinal studies also exist, which may provide useful information on associations, possible moderators that constraint the associations, and mediating mechanisms that explain them (Grimes & Schulz, 2002; Spector, 2019). In fact, to understand the aspects that may influence mental health outcomes, it is important to consider the task- and context-related constraints that shape their association with structured MA/CS practice, including MA/CS types, delivery mode and type, guidance, and settings (Bu et al., 2010; Pesce et al., 2021; Vertonghen & Theeboom, 2010). Therefore, moderating factors and mediating mechanisms that have been analysed to further our understanding of the broader relationship between physical activity and mental health (Pesce et al., 2021; Vergeer & Biddle, 2021) should be also considered to construct an evidence-based body of knowledge that can accommodate the complexities of MA and CS and inform mental health interventions, strategies, and policies. However, the relationship between MA/CS and mental health is composite and many-sided, with knowledge gaps including the lack of consensus on definitions and measures (Fogaça et al., 2021; Russo & Ottoboni, 2019), individual focus over sociocultural and environmental factors (Cooper & Lochbaum, 2022; Llopis-Goig, 2015; Palumbo et al., 2023), language barriers (Osipov et al., 2019), and the need for a broader technology-assisted approach to examine the role of cognitive functioning and brain structure/function (Koutures & Demorest, 2018; Naves-Bittencourt et al., 2015; Russo & Ottoboni, 2019).

Therefore, the present review aimed to: i) provide an overview of observational studies that assessed different facets of mental health in four domains (self, ill-being, well-being, cognition) among adult MA/CS practitioners; and ii) explore potential nuances of the reported associations according to potentially relevant individual-level (e.g., age, sex) and task-level (e.g., intensity of practice) moderators; iii) infer possible causal connections between MA/CS participation and the mental health outcomes from mediating mechanisms that may underlie MA/CS-mental health associations.

4. Methods

4.1. Protocol and search

The study protocol was registered on PROSPERO (Record ID: CRD42020154956) and the review followed the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement.

The Cochrane Library, EBSCOhost (including CINAHL, PsycARTICLES, Psychology and Behavioural Sciences Collection, PsycINFO, and SPORTDiscus), Scopus, ISI Web of Science (including Web of Science Core Collection, KCI-Korean Journal Database, MEDLINE, Russian Science Citation Index and Scielo Citation Index) databases were searched for papers from inception (i.e., 1965) to September 30, 2022. Automatic search alerts were maintained to identify new published papers since the initial search. Groups and single terms for MA/CS and for socio-psychological outcomes (e.g., mental health OR cognit × health OR psychological health […] AND martial art OR combat × sport OR fighting sport), and limiters for languages, and publication type were applied (Supplementary Material 1). Six languages were considered (English, French, Italian, Korean, Portuguese, Spanish), reducing the risk of language bias (Rico-González et al., 2022).

4.2. Inclusion and exclusion criteria

Inclusion and exclusion criteria were applied to participants, exposure, comparators, outcomes, and study designs. The PECO format (Morgan et al., 2018; Rico-González et al., 2022) was applied to identify quantitative cross-sectional and longitudinal studies (Grimes & Schulz, 2002) focusing on MA/CS adult (>18 years) practitioners not involved in complementary interventions (e.g., psychological and/or pharmacological treatments), and reporting at least one of the following quantitative measures of mental health outcomes (Lubans et al., 2016): i) self-related constructs (i.e., a set of psychological characteristics and aspects that relate to an individual's sense of self and identity such as self-esteem, body image); ii) ill-being including emotion-related conditions categorised in internalizing emotion regulation (i.e., involving difficulties with regulating emotions internally, such as depression, anxiety) and externalizing emotion regulation (i.e., challenges in regulating emotions directed towards others or the environment, such as hostility, anger); iii) well-being (i.e., a positively framed multidimensional construct encompassing states and skills, such as coping, and emotional competence-intelligence); iv) and cognition including the underlying brain health mechanisms (i.e., mental processes involved in acquiring, processing, and using information, such as attention, perception and memory). Additional included outcomes were mental health-related and, more specifically, cognition-related biological (e.g., neurotrophic factors) and brain structure and function (e.g., Magnetic Resonance Imaging [MRI] and Event-Related Brain Potential [ERP]) data. Comparisons were required, either between different MA/CS groups based on age, sex, athletic level, type of training guidance; or between MA/CS groups and other sports practitioners; or between MA/CS groups and control groups of physically inactive individuals. Exclusion criteria encompassed studies on youth (<18 yr) populations, acute MA/CS interventions (e.g., single session), activities not clearly recognizable as MA/CS, mental health outcomes not belonging to the included categories, lack of comparator/control groups, qualitative data, and experimental study design. Coded in alphabetical order (Supplementary Material 2), the retained papers are indicated in the present manuscript and in the tables between squared brackets (e.g., [1; 3]).

4.3. Data extraction and analysis

Data extraction focused on associations between MA/CS participation and mental health variables labelled as '0' (null; studies not supporting nor opposing the relationship), '+' (positive; supporting the relationship) or '−' (negative; opposing the relationship) (Sallis et al., 2000). The retrieved cross-sectional and longitudinal data related to statistical associations between different variables (i.e., mental health outcomes and MA/CS practice). These associations have been examined using various statistical tests such as t-tests, correlations, regressions, analysis of variance (e.g., ANOVA, ANCOVA), or non-parametric statistical tests (e.g., Mann-Whitney *U* test) for not-normally distributed data. The results of these statistical tests have been represented by p-values, where a p-value of less than 0.05 was generally considered statistically significant. Comparisons between MA/CS participants and other sports athletes, and between MA/CS participants and controls (often referred to as "non-athletes" with a level of physical activity often unspecified) were reported separately, as were potential moderating variables. To address the second aim of this review, we used the methodology suggested by Pesce et al. (2021). Therefore, data on multiple moderators were extracted from the individual studies: participant-, exposure-, context-, outcome – and study level moderators. Accordingly, we examined how many studies addressed each moderator and how many reported evidence of its influence. We coded as evidence of moderation a significant statistical difference between subcategories of the moderator in individual studies, or a difference in frequency of positive associations between subcategories in individual studies reported as meaningful by authors.

To analyse the data, we coded for study information (e.g., study types and duration, groups types, variables and outcomes) and grouped the variables according to the mental health categories described in Lubans et al. (2016) encompassing larger domains (e.g., ill-being) and sub-domains (e.g., internalizing and externalizing emotion regulation) to provide a more detailed and nuanced understanding of the information. The consistency of evidence was defined as 'limited inconclusive', 'limited suggestive', 'probable', 'convincing', or 'very convincing', if evidence of positive (i.e., indicating an improvement) outcomes was provided by < 25 %, 25 to <50 %, 50 to <75 %, 75 % to <100 %, 100 % of the samples, respectively. The strength of evidence was scored based on the quality of the studies. Conversely, as a result of the heterogeneity of mental health measures employed in the included studies and the limited number of studies investigating the same associations, a meaningful meta-analysis was not feasible.

4.4. Risk of bias

To Risk of bias was assessed by using the Cochrane Collaboration's Tool for Measuring Risk of Bias (Higgins et al., 2019) adapted for observational studies and widely used in previous systematic reviews (Castro et al., 2018; Poitras et al., 2016; World Health Organisation, 2020). The tool contains six items to appraise: i) Sampling bias (i.e., is the sampling method adequate?); ii) Detection bias (i.e., is the measurement of mental health outcome(s) adequate?); iii) Selection bias I – attrition (i.e., is the outcome data complete?); iv) Selection bias II – exclusions from the analysis (i.e., are exclusions from the analysis given and appropriate?); v) Selective reporting (i.e., is the report free from selective outcome reporting?); and vi) Confounding bias (i.e., did authors control for potential confounding variables?). Each potential source of bias was rated as high, low, or unclear based on pre-specified criteria (Supplementary Material 3). Two independent reviewers assessed the eligibility of the retrieved papers, performed the data extraction, and evaluated the risk of bias of the retained contributions. Any disagreement was resolved with a third reviewer.

5. Results

From an initial list of 8152 retrieved scientific contributions, 72 studies met the inclusion criteria (Figure 1). Table 1 shows the characteristics of the included studies. Twenty-six contributions were published between 1967 and 2010 (33 %), whereas 46 publications (77 %) were published in the 2011–2019 period, with a wide geographical representation (3 continents, 20 countries). All studies employed an observational design with most ($n = 70$, 97 %) being cross-sectional and only two studies using a prospective longitudinal design [13; 37]. Most of the studies were in English ($n = 65$, 90 %), six in Romance (e.g., French, Italian, Portuguese, Spanish) and one in Oriental (Korean) languages. For type of MA/CS, 23 studies covered MA disciplines developed in Japan (e.g., aikido, kendo, shorinji-kempo, karate, and judo) or

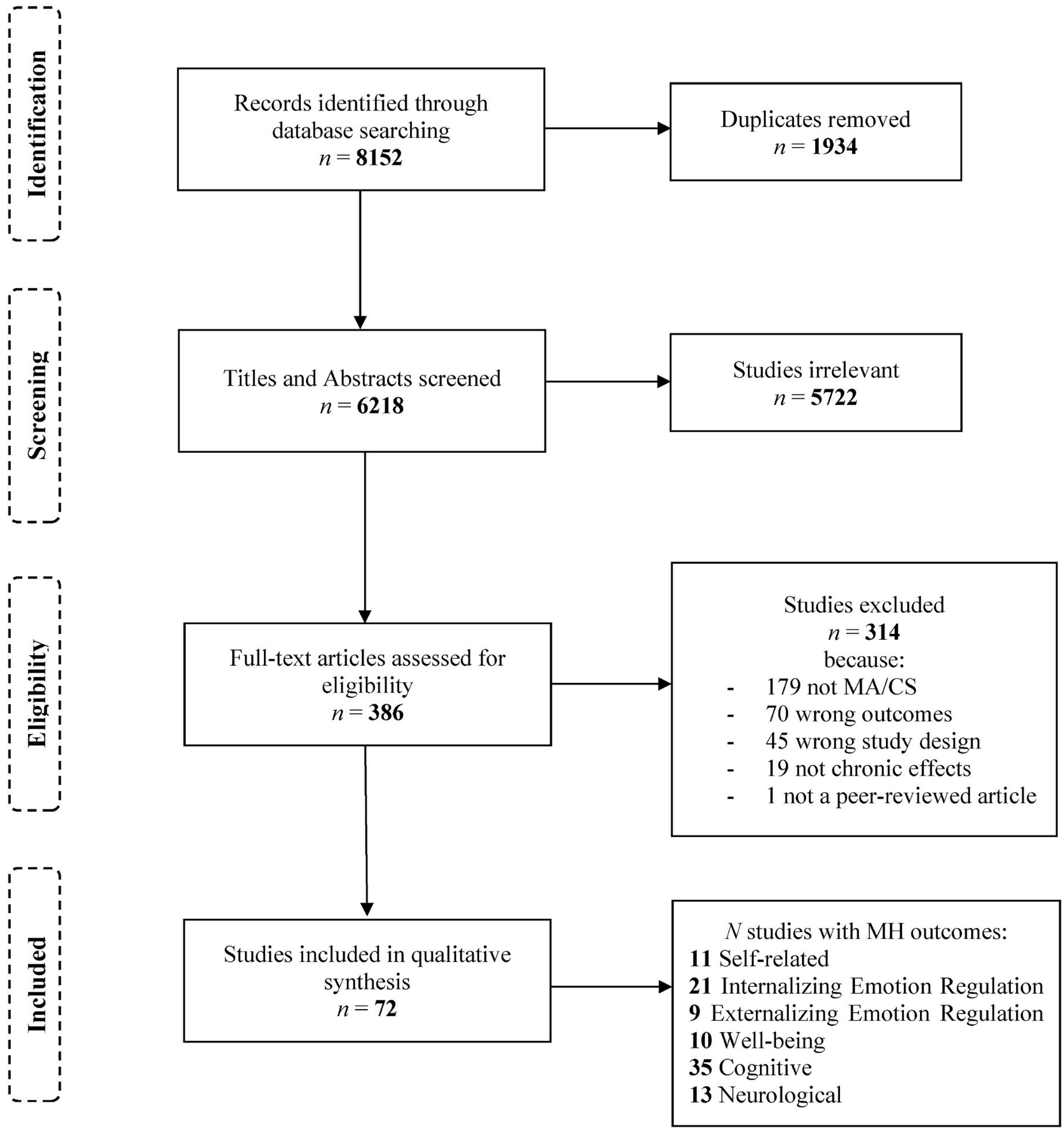

Figure 1. Flowchart of the literature search.
Note. *N/n*: number(s); MA/CS: Martial Art(s)/Combat Sport(s); MH: Mental Health.

derived from Japanese tradition (e.g., Brazilian jiu-jitsu); 23 studies focused on traditional Chinese (e.g., kung fu and tai chi) and Korean (e.g., taekwondo) disciplines; 20 studies concerned Western sports (e.g., capoeira, fencing, wrestling, boxing); and 22 studies involved multiple and one study [58] unspecified MAs. Additionally, 69 % and 31 % of studies covered "hard" (e.g., karate, boxing) and "soft" (e.g., aikido and judo) MA, respectively. Moreover, 39 % and 61 % of studies covered "traditional" and "modern" practices, respectively. Finally, whilst 67 % and 33 % of studies represented "external" and "internal" categories, respectively, 82 % of studies represented sports, whereas 18 % of studies covered "combat" styles. The contextual setting of the studies was related to sport ($n = 48$, 67 %), health ($n = 19$, 26 %), and higher education ($n = 5$, 7 %). Most of the studies ($n = 69$, 96 %) did not provide information on training guidance (e.g., details on programs, delivery modes and instructors).

A total of 12,115 individuals were investigated, ranging from nine to 3153 participants across group comparisons ($n = 3.4$ groups, $SD = 1.7$). Mean age of the participants was 26.5 years ($SD = 4.4$), with eight studies not providing this information (although including an adult population). In general, women were underrepresented (28.7 %) and 9 papers did not report the sex of participants. On average, MA/CS experience was 6.7 years ($SD = 4.1$), including competition, training and/or practice. Regarding the competition level, 35 studies included participants competing at high level (e.g., elite, international, national, and professional), whereas 10 studies included sub-elite, regional, and amateur athletes, 6 studies included non-competitors, and 30 studies reported no information. Most of the studies ($n = 48$, 67 %) provided no information on the MA/CS training load, 11 studies reported training frequency of 3.8 session·week^{-1} ($SD = 1.4$), 13 studies reported a training duration of 13 h week^{-1} ($SD = 12.4$), and few studies ($n = 4$, 6 %) reported information on course duration and intensity of efforts (e.g., MET). Eleven contributions addressed self-related outcomes, 21 internalizing emotion-regulation, 9 externalizing emotion-regulation, 10 well-being, 35 cognitive aspects, and 13 neurological and brain

Table 1
Characteristics of included studies.

Publication Years with:	Nr of Years	*Year* **[Reference Code]** *
1-3 publications·year^{-1}	16	*1967*[36]; *1975*[59]; *1987*[12]; *1988*[14; 17]; *1990*[19; 33]; *1991*[68]; *1992*[20]; *1993*[13; 51]; *1995*[41; 58]; *1999*[30]; *2001*[8; 3]; *2006*[26; 34]; *2007*[24; 31, 32]; *2008*[7; 64]; *2009*[18; 23]; *2010*[1]
4-6 publications·year^{-1}	9	*2011*[6; 15; 22; 23; 47; 61]; *2012*[9; 27; 42; 46; 62; 63]; *2013*[21; 53; 57; 65]; *2014*[39; 50; 56; 66; 70], *2015*[29; 60; 67]; *2016*[5; 38; 43; 44; 52; 71]; *2017*[16; 37; 48; 54, 55; 72]; *2018*[4; 10; 11; 28; 40; 69]; *2019*[8; 35; 45; 49]
First Authors with:	Nr of Authors	***First Author Name***[Reference Code]
2 publications	6	***Bianco***[7, 6]; ***Daniels***[19, 20]; ***Filaire***[31, 32]; ***Kolayis***[46; 47]; ***Leznicka***[54, 55]; ***Moreau***[62; 63]
3 publications	2	***Del Percio***[23, 24, 25]; ***Muinos***[65, 66, 67]
Countries with:	Nr of Countries	***Country***[Reference Code]
1-4 Study/ies	20	***Belgium***[11; 50]; ***Brazil***[70]; ***Canada***[30]; ***China***[[15]; ***Former-Yugoslavia&Turkey***[8]; ***Finland***[3; 59]; ***France***[31, 32]; ***Germany***[10; 38; 44]; ***Greece***[18]; ***Iran***[9; 42]; ***Japan***[35; 45; 56]; ***Korea***[5; 39]; ***Norway***[69]; ***Portugal***[22]; ***Romania&Turkey***[4]; ***Serbia***[8; 27; 61]; ***Sweden***[68]; ***USA&France***[63]; ***Taiwan***[16; 52]; ***Turkey***[28; 43; 46; 47]
6-10 Studies	5	***Italy***[1; 7, 14; 17; 22–26; 34]; ***Poland***[21; 48; 49; 53–55; 64; 72]; ***Spain***[29; 60; 65–67; 71]; ***UK***[12; 13; 19, 20; 37; 40; 41]; ***USA***[33; 36; 51; 57; 58; 62]
Languages	Nr of Studies	[Reference Code]
English	65	[1–13; 15; 16; 18–21; 23–30; 32–38; 40–59; 61–69; 71; 72]
French	1	[31]
Italian	2	[14; 17]
Portuguese	1	[70]
Spanish	2	[22; 60]
Korean	1	[39]
Study/ies on:		***MA/CS***[Reference Code]
Aikido	1	[57]
Brazilian Ju-Jitsu	1	[69]
Kendo	1	[35]
Kung Fu	1	[65]
Shorinji-Kempo	1	[17]
Capoeira	2	[44; 70]
Fencing	2	[15; 26]
Tai Chi Chuan	2	[52; 56]
Taekwondo	3	[33; 39; 51]
Wrestling	4	[36; 59; 62; 72]
Karate	9	[1; 22; 23; 25; 28; 30; 34; 46; 71]
Judo	10	[14; 21; 27; 29; 31, 32; 43; 45; 47; 61]
Boxing	12	[2; 5; 6; 7, 12; 13; 37; 38; 41; 42; 53; 68]
Multiple MA/CS	23	***Aikido/Judo/Karate***[50]; ***Boxing/Brazilian Ju-Jitsu/Karate/MMA/Muay-Thai Boxing***[49]; ***Boxing/Escrima/Freefight/Judo/Ju-Jitsu/Karate/MMA/Muay-Thai/Wing-Tsun***[10], ***Boxing/Kickboxing***[60]; ***Boxing/Judo/Karate/Taekwondo/Wrestling***[4]; ***Boxing/Karate/MMA***[54, 55]; ***Boxing/Wrestling***[3]; ***Fencing/Karate***[24]; ***Fencing/Judo/Wrestling***[63]; ***Fencing/Taekwondo***[11]; ***Judo/Ju-Jitsu/Karate/Kickboxing/Kung-Fu/Taekwondo/Tai-Chi/Thai Boxing***[40]; ***Judo/Ju-Jitsu/Karate/Kickboxing/MMA/Taekwondo/Wrestling***[8]; ***Judo/Karate***[66, 2015]; ***Judo/Pszczynska Martial Art***[48]; ***Judo/Taekwondo***[18] ***Karate/Judo/Wrestling***[64]; ***Karate/Ju-Jitsu***[19, 20]; ***Karate/Kickboxing***[9]; ***Karate/Taekwondo***[16]; ***Unspecified***[58]
Settings:	Nr of Studies	[Reference Code]
Health	19	[5; 10; 12; 13; 16; 35; 37; 38; 41; 44; 49; 51; 52; 53; 56; 57; 61; 62; 70]
Sport	48	[1–4; 6; 7, 9; 11; 14; 15; 17–32; 34; 40; 42; 43; 45–48; 50; 54, 55; 59; 60; 63–69; 71; 72]
University	5	[8; 33; 36; 39; 58]
Guidance	Nr of Studies	***Info on Guidance***[Reference Code]
Info	3	***Presence and respect to "Sensei"***[19]; ***Nosanchuk's criteria for a 'traditional' martial art***[20]; ***Specific item of MPS questionnaire***[32]
No Info	69	[1–18; 21–31; 33–72]
Participants	Nr	[Reference Code]
Total	12,115	*All studies*
Min	9	[5]
Max	3153	[3]
Groups	Nr	[Reference Code]
Mean (SD)	3.4 (1.7)	*All studies*
Min	2	[2; 5–8; 10–12; 15; 17; 18; 20; 21; 23, 25–28; 30; 33; 35; 37; 39; 40; 48; 51; 53–55; 62; 63; 65; 70; 72]
Max	9	[31]
Sex of Participants	%	[Reference Code]
Male	71.3	[1; 3; 5–8; 10–16; 18; 20; 22–25;
Female	28.7	27–29; 31–35; 37–72]
N/A		[2; 4; 9; 17; 19; 21; 26; 30; 36]
Age	Years	[Reference Code]
Mean (SD)	26.5 (4.4)	[1–35; 37–42; 44–55; 58; 60; 62; 63; 65–72]
N/A		***University athletes***[36]; ***Athletes of three age classes: 15–19 years old, 20–25 years old, >25 years old***[43]; ***>31 years old Tai Chi practitioners***[52]; ***>60 years old Tai Chi practitioners***[56]; ***Adult Aikido practitioners***[57]; ***Adult MA/CS athletes***[59]; ***17–24 years old judoka***[61]; ***19–34 years old CS athletes***[64]
Expertise in MA/CS	Years	[Reference Code]
Mean (SD) *Years of Experience: Practice/Training/Competition*	6.7 (4.1)	[2; 6–8; 10; 12; 13; 15; 18–20; 22; 27–31; 33–35; 37; 38; 40–47; 51; 52; 54; 55; 57; 60; 63; 65–70; 72]
N/A		[3; 4; 5; 9; 11; 21; 32; 36; 39; 48; 50; 53; 56; 58; 59; 61; 62; 64; 71]
Competitive level in MA/CS	Nr of Studies	[Reference Code]

(continued on next page)

Table 1 (*continued*)

Publication Years with:	Nr of Years	*Year* **[Reference Code]** *
Elite/International/ National/Professional	35	[1–5; 7; 9; 11; 18; 21; 23–26; 28; 29; 31, 32; 38; 41; 43; 45; 47; 49; 53; 59–63; 65–67; 69; 72]
Sub-elite/Regional/ Amateur	10	[6; 7; 12; 13; 38; 41; 42; 60; 68; 69]
Not competing	6	[17; 49; 63; 66; 69; 70]
N/A	30	[8; 10; 14–16; 19, 20; 22; 27; 30; 33–37; 39; 40; 44; 46; 48; 50–52; 54–58; 64; 71]
Training Load in MA/CS	Nr of Studies	***Info on Training Load***[Reference Code]
N/A	48	[3–11; 13–15; 17; 20; 21; 26; 28; 30; 34; 36–44; 46–49; 51; 53–55; 57–59; 61–64; 66–68; 71; 72]
	Times·Week^{-1}	
Frequency 1: Mean (SD)	3.8 (1.4)	[1; 19; 23; 24; 25; 29; 35; 45; 52; 60; 70]
	Hours·Week^{-1}	
Frequency 2: Mean (SD)	13 (12.4)	[16; 18; 22; 27; 29; 31, 32; 45; 50; 60; 65; 69; 70]
Other Info	–	General info on participation in trainings, competitions, psychological preparation[8]; Mean Nr of Bouts ± SD: 26.2 ± 22.2[12]; Course duration: 8 Weeks[33] 3.3 METs·Hours·Week^{-1}[56]
Study Type	Nr of Studies	[Reference Code]
Cross-sectional Studies	70	[1–12; 14–36; 38–72]
Prospective Studies	2	[13; 37]
Category of MH Outcomes	Nr of Studies	*Instruments/Tests*[Reference Code]
Self-related	11	*Cooper Smith Self-esteem Inventory; Kentucky Inventory of Mindfulness Skills-KIMS; Learning Observer's Coding; 2001 Mendelson, Mendelson & White's Body Esteem Scale-BES; Mindfulness Attention Awareness Scale; Multidimensional Body-Self Relations Questionnaire-MBSRQ; Multidimensional Perfectionism Scale-MPS; 1982 Ryckman et al. Physical Self-Efficacy Scale; Rosenberg's Self-Esteem Scale; Sociocultural Attitudes Toward Appearance-SATAQ; Tennessee Self-concept Scale*[8; 18; 31–33; 39; 47; 48; 55; 57; 69]
Internalizing Emotion Regulation	21	*Beck Depression Inventory; Brief Symptom Inventory- BSI-53; Eating Attitudes Test-EAT-26 & EAT-40; Eating Disorder Examination Questionnaire & Eating Disorder Inventory-2-EDI-2; Food Craving Questionnaire-Trait-FCQ-T; Formal Characteristics of Behaviour Temperament Inventory-FCZ-KT; Form C of the 16 Personality Factor Questionnaire; Geriatric Depression Scale-GDS; IPAT Anxiety Scale; Minnesota Multiphasic Personality Inventory-MMPI; 2011 Mitic Coping Style Questionnaire; Profile of Mood States-POMS; K6 scale; Restraint Subscale RS-CD; 1966 Rotter's Internal-External Control of Reinforcement Scale; Spielberger State-Trait Anxiety Inventory-STAI; Taylor Manifest Anxiety Scale; Two-Dimensional Inventory of Emotional Intelligence; Yesevage's depression scale; Zung Self-Rating Depression Scale-SDS*[2; 3; 5; 14; 18; 29; 31, 32; 36; 39; 43; 45–47; 51; 54; 56; 58; 59; 61; 70]
Externalizing Emotion Regulation	9	*Barratt Impulsiveness Scales; Buss-Durkee Hostility Inventory; Koshenvuo Hostility test; 1992 Buss & Perry's Aggression Questionnaire; Fragebogen zur Erfassung von Aggressivitätsfaktoren-FAF; Rorschach Test; Spielberger's STAXI-2 Self-assessment Questionnaire; State-Trait Anger Expression Inventory*[3; 9; 10; 19, 20; 21; 59; 60; 64]
Well-being	10	*Allardt's 1973 scale; 1987 Argyle's Sense of Happiness Questionnaire; 1992 Bammel & Burrus-Bammel's Leisure Benefits Scale; Brief-COPE Inventory; Cognitive and Emotional Empathy Questionnaire; Coping Inventory for Stressful Situations-CISS; Emotional Competence Questionnaire; Emotional Quotient Inventory Bar-On:EQ-i; Mindfulness Attention Awareness Scale-MAAS; Scheler's Value Scale; UCLA Loneliness Scale; World Health Organization Quality of Life BREF Questionnaire*[3; 18; 43; 44; 48; 49; 52; 54; 61; 72]
Cognitive	35	*Alternating Tapping Test; Anticipation Speed KCC Test; Attention Network Test-ANT; Benchmark Test; Cambridge Neuropsychological Test Automated Battery-CANTAB; Claeson-Dahl Test; Cognitive State Questionnaire; Computerized NeuroPsychological Test Battery-CogSport; Covert Orienting of Visual Attention-COVAT Task Test; Cuadro de Schulte; DAUF-Sustained Attention Test under Vienna Testing System; Digit Span Test; Dynamic visual acuity-DVA; FingerNoseFinger-FNF Test; Go/No-Go Reaction Time Task; Hit-the-dots Reaction Test; Hopkins Verbal Learning Test; IQ - HAWIE-R test; Koh's test; Konzentration Verlaufs Test- KVT; Luria Test; Memory for Design Test; Mental Rotation, Visual and Spatial Memory Spans Tests; Mill Hill Vocabulary Scale; Mini Mental State Examination; Modified Stop Signal Task-SST; Multiple Choice Vocabulary Test; Paced Auditory Serial Addition Task-PASAT; Posner's Attentional Test; Kinesthetic Empathy Scale; Raven's Progressive matrices; Rey-Osterrieth Complex Figure Test; Simple and Choice Reaction Time Task Test; Special Ability Signal Test; Trail Making Test-B; Toulouse-Pieron Test; Wechsler Adult Intelligence Scale; Wechsler Memory Scale; Zimmerman and Fimm's Attentional Test; 1994 Bouffard-Bouchard adapted coding scheme*[4–7; 10–13; 15–17; 22–24; 26; 30; 34; 35; 37; 38; 40–42; 45; 48; 50; 53; 62; 63; 65–68; 70; 71]
Neurological	13	*Cambridge Neuropsychological Test Automated Battery-CANTAB; Electroencephalography-EEG; Electromyoneurography-EMNG; F-FDG PET; FMZ PET; Low Resolution Electromagnetic Source Tomography-LORETA; Nystagmus Test; Purdue Pegboard Test; Romberg Test; Structural MRI*[1; 5; 10; 12; 24; 26–28; 35; 37; 38; 41; 68]

Note. F-FDG: F-FluoroDeoxyGlucose; FMZ: Flumazenil; IPAT: Institute for Personality & Ability Testing; MA/CS: Martial Art(s)/Combat Sport(s); MET: Metabolic Equivalent of Task; MRI: Magnetic Resonance Imaging; N/A: Not Available; Nr: Number; PET: Positron Emission Tomography; SD: Standard Deviation. §Reference codes refer to the numbered list of included studies, which can be found in Supplementary Material 2.

functions and structure-related outcomes.

5.1. Self-related constructs

Six outcomes were grouped under self-related constructs according to how they were examined in the respective studies: self-esteem, perfectionism, self-concept, body image, mindfulness, and values (Table 2). However, only self-esteem, perfectionism and body image were studied in more than two samples. Comparisons of self-esteem (i.e., subjective construct reflecting the degree to which individuals appraise and value themselves) in MA/CS athletes versus other sports athletes reported mixed results, showing both no difference [31; 32] or lower levels of self-esteem in MA/CS athletes [8; 31; 32]. Mixed results emerged also for comparisons of self-esteem in MA/CS versus non-sport groups, with MA/CS showing higher [39; 48] or lower [32] levels, or no differences [31; 32]. No moderating effects [8; 31] for age, sex, sport exposure, or anxiety emerged (Table 3). Comparisons of perfectionism (i.e., personality trait characterized by a person's striving for flawlessness and setting excessively high-performance standards, accompanied by overly critical self-evaluations and concerns regarding others' evaluations) of MA/CS athletes with other sports athletes and with controls showed no differences and no moderating effect for sex [31; 32]. Mixed results emerged also for comparisons of body image (i.e., individuals' concept of their own bodies) in MA/CS versus non-sport groups, with MA/CS showing higher [18] or lower [18; 39] levels, or no differences [18]. Overall, cross-sectional data provided negligible or absent associations of participation in MA on self-related variables, with limited inconclusive consistency and strength of evidence of positive associations (Supplementary Material 4).

5.2. Ill-being

5.2.1. Internalizing emotion regulation

Sufficient evidence on internally focused emotion regulation was available for anxiety, depression, and eating disorders (Table 2). For anxiety (i.e., feelings of tension and worry), comparisons between MA/CS athletes and other sports athletes showed either no difference [2; 3; 14; 36; 59; 61] or lower levels for MA/CS [14; 59; 61]. No difference emerged for comparisons between MA/CS and controls [3; 18; 36]. Effects for moderators were mixed for sex, exposure, and some psychological variables (Table 3 and Supplementary Material 4).

For depression (i.e., episodes of unhappiness, ranging from recurrent low mood and inability to find enjoyment, to more extreme dissatisfaction with life), no difference emerged comparing MA to other sports athletes [3; 58; 70] or controls [3; 5], with a moderating role attributed to the length of MA training on lower depression [56]. For disordered eating (behavioural conditions characterized by severe and persistent disturbance in eating behaviours and associated distressing thoughts and emotions), no differences were found comparing MA/CS to other sports athletes [31], whilst comparisons to controls showed either no difference [18; 31; 39] or a higher incidence in MA/CS [32; 39]. Results for moderators were mixed (Table 3 and Supplementary Material 4). Overall, positive associations with internalizing emotion regulation were limited inclusive for both consistency and strength of evidence (Table 4). As moderators, exposure may be considered for anxiety and depression, and sex for eating disorders.

5.2.2. Externalizing emotion regulation

For external emotion regulation, evidence on emotions as well as behaviours underpinned by emotions was available for aggression, hostility, and anger (Table 2). For aggression (i.e., behaviours which may be manifested by verbal or physical destructive and attacking action, by covert attitudes of hostility or by obstructionism), comparisons between MA/CS and athletes from other sports indicated mixed results for different aspects of aggression, with higher scores for karate and kickboxing compared to other sports on physical aggression, and for total and verbal aggression for kickboxing [9]. For karate, total and verbal aggression were no different from other sports [9]. Comparisons of aggression with non-sport groups showed mixed results [9; 10]. Comparisons of aggression between samples of different MA found consistently lower scores for karate compared to kick boxing, judo, wrestling [9; 64]. No other moderators were studied for aggression (Table 3 and Supplementary Material 4).

For hostility (i.e., tendency to feel anger toward and to seek to inflict harm upon a person or group), comparisons between MA/CS athletes and athletes from other sports found mixed results, with higher hostility for kickboxers [9], and no differences for karate [9; 19], wrestling and boxing [3], and jiu-jitsu [19]. Comparisons of hostility in MA athletes to non-sport control groups reported also mixed results, with no difference in overall hostility and some aspects of hostility compared to controls in kickboxing, wrestling and boxing, karate, and jiu-jitsu [3; 9; 19]. Comparisons of hostility between samples of different types of MA reported higher hostility scores for kickboxing compared to karate [9], and similar hostility scores for karate and jiu-jitsu [19]. Exposure was examined as a moderator, showing a negative relationship between length of training and assaultive hostility for karate, though no relationship for verbal, indirect or combined hostility [19]. For jiu-jitsu, no relationship was reported with any of the hostility subscales [19]. Combining karate and jiu-jitsu, higher hostility scores were found among beginners compared to controls, intermediate and advanced practitioners, while lower hostility scores were found for advanced practitioners compared to controls, beginners, and intermediate. For a combined karate/ju jitsu sample [20], a negative relationship was found between length of training and assaultive and verbal hostility, but not indirect hostility (Supplementary Material 4).

For anger (i.e., strong emotional feeling of displeasure aroused by being interfered with, injured or threatened), kickboxers scored higher than other sports [9], while no differences were found for karateka (i.e., karate practitioners) [9]. Comparisons of anger between MA/CS athletes and non-sport control groups reported mixed results, with no difference for national and international combat sport athletes on several subscales of anger [21; 60]. Comparing different MA samples, kickboxers presented higher anger scores than karateka [9].

In summary, both in terms of consistency and strength of evidence the limited positive relationships observed for externalizing emotion regulation concepts may be moderated by length of training (with longer involvement associated with lower scores), and possibly level of competitive engagement, although this could be confounded with length of training (Table 3 and Supplementary Material 4). Differences within MA/CS types may also affect the relationship.

5.2.3. Well-being

Of seven outcomes grouped under wellbeing (Table 2), sufficient evidence was available for coping, emotional competence/intelligence, control and loneliness. For coping (i.e., state of harmony between internal needs and external demands and the processes used in achieving this condition), MA/CS athletes were higher on task-oriented and lower on avoidance-oriented coping than other sports athletes, with no difference for emotion-oriented coping. Compared to non-sport controls, MA/CS scored higher on active coping and positive reframing, lower on "turning to religion", with no differences for other types of coping. Sex was a moderator in one study [72].

For emotional competence/intelligence (i.e., ability to understand and manage emotions and to use emotional knowledge to enhance thought and deal effectively with tasks), comparisons with other sport

Table 2
Descriptive summary of the positive, negative and null associations between MA/CS participation and outcomes related to self, emotion, well-being, cognition, brain function and structure.

OUTCOMES		SUBCATEGORY	COMPARISONS	ASS	MA/CS[Reference Code][§]
SELF-RELATED CONSTRUCTS		*SELF-ESTEEM**	MA/CS vs S	-	CS competitors[8]; judo[31]
				0	judo[31]
			MA/CS vs C	+	taekwondo[39]; MA[48]
				-	judo[32]
				0	judo[31; 32]
		*PERFECTIONISM**	MA/CS vs S	**0**	judo[31]
			MA/CS vs C	**0**	judo[31; 32]
		SELF-CONCEPT	MA/CS vs C	+	taekwondo[33]
				0	taekwondo[33]
		*BODY IMAGE**	MA/CS vs C	+	judo, taekwondo[18]
				-	judo, taekwondo[18]; taekwondo[39]
				0	judo, taekwondo[18]
		MINDFULNESS	MA/CS vs C	+	aikido[57]
		VALUES	MA/CS vs C	+	judo, *Pszczynska* MA[48]
				-	judo, *Pszczynska* MA[48]
				0	judo, *Pszczynska* MA[48]
ILL-BEING	**INTERNALIZING EMOTION REGULATION**	*ANXIETY**	MA/CS vs S	-	judo[14; 61]; MA students[59]
				0	boxing[2]; wrestling, boxing[3]; judo[4; 61]; wrestling[36]; MA students[59]
			MA/CS vs C	**0**	wrestling, boxing[3]; taekwondo, judo [18]; wrestling[36]
		*DEPRESSION**	MA/CS vs S	**0**	wrestling, boxing[3]; MA students[58]; capoeira[70]
			MA/CS vs C	**0**	wrestling, boxing[3]; boxing[5]
		*DISORDERED EATING**	MA/CS vs S	**0**	judo[31]
			MA/CS vs C	+	judo[32]; taekwondo[39]
				0	judo, taekwondo[18]; judo[31]; taekwondo[39]
	EXTERNALIZING EMOTION REGULATION	*AGGRESSION**	MA/CS vs S	+	karate, kickboxing[9]
				0	karate[9]
			MA/CS vs C	+	kickboxing[9]; Asian MA[10]
				-	MA students[59]
				0	karate, kickboxing[9]; Asian MA[10]; MA students[59]
			MA/CS vs MA/CS	+	kickboxing > karate[9]
				-	karate < judo/karate < wrestling[64]
				0	judo = wrestling[64]
		*HOSTILITY**	MA/CS vs S	+	kickboxing[9]
				0	wrestling, boxing[3]; karate[9]; karate, jiujitsu[19]
			MA/CS vs C	-	karate[9]
				0	wrestling, boxing[3]; karate[9]; karate, jiujitsu[19]
			MA/CS vs MA/CS	+	kickboxing > karate[9]
				0	[19]karate = ju-jitsu
		*ANGER**	MA/CS vs S	+	kickboxing[9]
				0	karate[9]
			MA/CS vs C	+	kickboxing[9]; judo[21]
				-	karate[9]; national & international CS[60]
				0	judo[21]; regional, national & international CS[60]
			MA/CS vs MA/CS	+	kickboxing > karate[9]
WELL-BEING		*EMOTIONAL COMPETENCE-INTELLIGENCE**	MA/CS vs S	+	judo[61]
				0	judo[61]
			MA/CS vs C	+	judo, taekwondo[18]
				-	boxing, karate, MMA[55]
				0	judo, taekwondo[18]
		*COPING**	MA/CS vs S	+	judo[61]
				-	judo[61]
				0	judo[61]
			MA/CS vs C	+	boxing, karate, MMA[55]
				-	boxing, karate, MMA[55]
				0	boxing, karate, MMA[55]
		LIFE SATISFACTION	MA/CS vs S	-	boxing, wrestling[3]
			MA/CS vs C	+	boxing, wrestling[3]
		LONELINESS	MA/CS vs S	-	judo[43]
				0	judo[43]
			MA/CS vs C	-	judo[43]
		*EMPATHY**	MA/CS vs S	+	capoeira[44]
				0	capoeira[44]
		MENTAL HEALTH	MA/CS vs S	**0**	judo[45]; capoerira[70]
		*CONTROL**	MA/CS vs S	+	MA students[58]

(*continued on next page*)

Table 2 (*continued*)

OUTCOMES	SUBCATEGORY	COMPARISONS	ASS	MA/CS[Reference Code]§
			-	MA students[58]
			0	MA students[58]
COGNITIVE FUNCTION	*GENERAL NEURO-PSYCHOLOGICAL STATUS*	MA/CS vs C	**0**	boxing[5]; capoeira[70]
	EXECUTIVE FUNCTION	MA/CS vs S	**0**	boxing, judo, karate, taekwondo, wrestling [4]; boxing[42; 68]
		MA/CS vs C	+	fencing, taekwondo[11]; fencing[15]; wrestling[62]; kung fu[65]
			-	boxing[38]; wresting[62]
			0	boxing[5; 12; 38]; fencing, taekwondo [11]; fencing[15]; multiple MA/CS[40; 50]; wrestling[62]; kung fu[65]; capoeira [70]
		MA/CS vs MA/CS	+	multiple MA/CS (↑years of practice = ↑executive control)[40]; elite > novice MA/CS[63]
			-	boxing (↓spatial-plan latency from pre-bout to post-bout)[37]
			0	boxing (professional = amateur)[7]; boxing (male = female)[6]; karate (high = low experience)[34]; boxing (longitudinal) [37]; boxing (amateur = novice)[42]; multiple MA[50]; MA/CS (elite = novice) [63]; boxing (high = low match)[68]
	LEARNING AND MEMORY	MA/CS vs S	**0**	boxing[13; 68]
		MA/CS vs C	+	boxing[12]
			-	boxing[5; 38; 41]
			0	boxing[5; 12]
		MA/CS vs MA/CS	+	karate (↑experience = ↑ learning strategies)[30]
			-	boxing (↑n. Of bouts = ↓pattern recognition accuracy)[41]
			0	boxing (longitudinal; high vs low n. Of competitions)[37; 41; 68]
	ATTENTION AND INFORMATION PROCESSING SPEED	MA/CS vs S	+	multiple MA/CS[4]; Shorinji-kempo[17]; judo & karate[66]
			0	boxing[13; 42; 68]; judo & karate[66]; karate[71]
		MA/CS vs C	+	fencing & taekwondo[11]; karate & taekwondo[16]; karate[23; 71]; fencing [26]; fencing & kendo[35]; multiple MA [40; 66]
			-	karate[23]; boxing[41]
			0	boxing[12; 38; 53]; fencing[15; 26]; karate [16; 24; 71]; kendo[35]; multiple MA[40; 50; 66]; capoeira[70]
		MA/CS vs MA/CS	+	boxing (professional = ↑simple reaction time)[7]; taekwondo (↑upper body reaction time) vs karate[16]; Shotokan karate (↑choice/decision accuracy in Dan vs 1–3 and 4–9 kyu athletes)[22]; multiple MA(↑years practice = ↑spatial orienting) [40]
			-	Shotokan karate (↑choice/decision time in Dan vs 1–3 and 4–9 kyu athletes)[22]; boxing (↓attention from pre-bout to post-bout)[37]; boxing (↑n. Of bouts = ↑choice reaction time)[41]
			0	boxing (professional = amateur)[7]; boxing (male = female)[6]; taekwondo vs karate (similar lower body reaction time) [16]; karate (elite = amateur)[24]; Shotokan karate (similar reaction time in Dan vs 1–3 and 4–9 kyu athletes)[22]; karate (high = low experience)[34]; boxing (similar processing speed from pre-bout to post-bout)[37]; boxing (amateur = novice)[42]; multiple MA (similar working memory, processing speed, simple reaction time)[50]; boxing (high = low n. Of matches)[68]
	INTELLIGENCE	MA/CS vs S	**0**	boxing (verbal understanding)[68]
		MA/CS vs C	+	MA/CS[10]; boxing (problem solving)[12]
			-	boxing (intellectual performance)[38]
			0	boxing (verbal intellect)[12]

(*continued on next page*)

Table 2 (*continued*)

OUTCOMES	SUBCATEGORY	COMPARISONS	ASS	MA/CS[Reference Code]§
		MA/CS vs MA/CS	**0**	boxing (high = low n. Of matches)[68]
	PERCEPTION	MA/CS vs S	+	judo & karate[67]
			0	judo & karate[66; 67]
		MA/CS vs C	+	judo & karate[67]
			0	judo & karate[66; 67]
BRAIN STRUCTURE	*GREY MATTER (MRI)*	MA/CS vs S	**0**	boxing[5; 37]; MA/CS[10]
		MA/CS vs MA/CS	**0**	boxing (longitudinal: from pre-bout to post-bout)[37]
	WHITE MATTER (MRI, DTI)	MA/CS vs C	-	boxing[38]
			0	boxing[5; 37]
		MA/CS vs MA/CS	**0**	boxing (longitudinal: from pre-bout to post-bout)[37]
	CORTICAL THICKNESS	MA/CS vs C	**0**	boxing[37]
		MA/CS vs MA/CS	**0**	boxing (longitudinal: from pre-bout to post-bout)[37]
	CEREBROSPINAL FLUID	MA/CS vs C	**0**	boxing[5]
	TOTAL BRAIN VOLUME	MA/CS vs C	**0**	boxing[5]; MA/CS[10]
	VOLUME OF SPECIFIC BRAIN REGIONS	MA/CS vs C	**0**	boxing (amygdala and hippocampal volume)[5]
	NEURONAL VIABILITY AND RECEPTOR DENSITY	MA/CS vs C	+	boxing[5]
			-	boxing[5]
BRAIN FUNCTION	*BRAIN METABOLISM*	MA/CS vs C	-	boxing[5]
	BRAIN OXYGENATION/PERFUSION	MA/CS vs C	+	kendo & fencing (motivation network)[35]; boxing[41]
			0	kendo & fencing (attention network)[35]
	ELECTROENCEPHALOGRAPHY (EEG)	MA/CS vs C	+	karate[1; 28]
			0	karate[28]
		MA/CS vs MA/CS	+	karate (elite = amateur)[1]
	VISUAL EVOKED POTENTIALS (VEPS) AND EVENT-RELATED POTENTIALS (ERPS)	MA/CS vs C	+	fencing[26]; judo[27]
			0	karate[24]; fencing[26]; judo[27]
		MA/CS vs MA/CS	+	karate (strongly lower P3, P4 peak amplitude for sport-specific karate stimuli in elite vs amateur karateka)[24]
			0	karate[24]

Note: ASS = association(s); C = non-sport comparison groups; DTI = Diffusion tensor imaging; F = female participants; M = male participants; MA = Martial Arts practitioners; CS = Combat Sports practitioners; MMA = Mixed Martial Arts; MRI = Magnetic Resonance Imaging; S = Sport practitioners comparison group(s); + = positive relationship; - = negative relationship; 0 = no relationship. Only outcomes that were studied in three or more samples have been described in the text. These are indicated with "*". For a detailed description of the associations please see Results section and Supplementary Material 4. §Reference codes refer to the numbered list of included studies, which can be found in Supplementary Material 2.

athletes showed higher scores for MA/CS on emotional competence and governing emotions, with no differences for understanding and expressing emotions. Comparisons with non-sport controls showed a positive relationship for assertiveness, a negative for emotional reactivity, and no difference for several other dimensions. Sex moderated the association between MA/CS participation and some dimensions (Supplementary Material 4) [18; 72].

For control (i.e., individual's ability to manage and monitor their emotions, behaviours, and desires in the face of external demands in order to function in society), comparisons with other sport athletes showed higher and lower scores for MA/CS as well as no differences [58]. For loneliness (i.e., state of feeling sad or dejected as a result of lack of companionship or being separated from others), comparisons with other sport athletes showed either lower scores for MA/CS or no differences [43], whereas compared with non-sport controls MA/CS athletes showed lower scores [43].

Overall, the results for these four outcomes indicate some positive relationships for emotion regulation resources such as task-oriented coping, emotional competence, and assertiveness, and some negative relationships for less helpful regulation strategies such as avoidance-oriented coping and emotional reactivity, with sex emerging as a potential moderator (Table 3 and Supplementary Material 4).

6. Cognitive functioning, brain structure and function

Cognition reflects the integration of several underlying processes. MA/CS researchers have targeted specific component processes: perception and detection, attention and processing speed, executive functions and strategy, and learning and memory. Across these categories are studies that focused specifically on boxing and the ramifications of full-contact strikes to the head. As such, research on MA/CS studies that limit full contact practice or competition are described separately from boxing. In the following sections, we summarize evidence provided from the studies that address hypothesized relations between MA/CS practice and the component process that underlie cognition. Table 2 provides the categorization scheme used to summarize the associations between MA/CS and cognition- and brain-related functions and structures.

6.1. Perception and detection

Extensive MA practice (kung-fu, judo, karate) benefits peripheral visuospatial perception and dynamic perceptual acuity, which reflects the ability to detect details of an object when it is moving. In fact, MA athletes were faster and more accurate on computerized speeded visuospatial- and hand-tapping motor-tasks. Examination of young and older MA practitioners' performance suggests that consistent MA practice may offset age-related declines in perceptual processes [65–67].

6.2. Attention and processing speed

MA/CS practice stresses the importance of automatic and reflexive-like responses. Four sub-sets of studies examine how repeated pairing of perceptual sensory experiences with specific movement patterns

Table 3
Moderators of associations between martial arts/combat sports participation and mental health outcomes in the selected studies.

Level	Moderator	Studies addressing the moderator (%)	[Reference Codes]	Studies suggesting an influence of the moderator (%)	[Reference Codes]§
PARTICIPANT	*Age*	**31**	[1; 3; 6; 12; 18; 19; 22; 24; 25; 30; 38; 41; 42; 44; 46; 47; 52, 56; 60; 65; 67; 71]	**8**	[6; 22; 46; 47; 52; 67]
	BMI	**4**	[35; 49; 55; 56]	**1**	[55]
	Education	**10**	[7; 41; 43; 46; 52; 56; 68]	**4**	[43; 46; 52]
	Expertise	**17**	[7; 12; 13; 15; 19; 22; 29; 38; 44; 56: 69; 71]	**10**	[7; 15; 19; 22; 29; 44; 69]
	Length of training	**14**	[19; 20; 40; 43; 44; 51; 52; 56; 60; 67]	**11**	[19; 20; 43; 44; 51; 52; 56; 67]
	Level of competitive engagement	**6**	[36; 61; 63; 67]	**4**	[36; 61; 67]
	Weight category	**3**	[7; 12]	**0**	–
	Sex	**18**	[1; 18; 22; 29; 44; 45–48; 52; 56; 71; 72]	**13**	[18; 22; 29; 45–48; 52; 72]
EXPOSURE	*Dose (quantity)*	**54**	[1; 6; 7; 12; 13; 15; 18–20; 22; 24; 27–29; 31–33; 35; 36; 38; 40; 43–45; 50–52; 55; 56; 59–63; 65; 67; 69; 71; 72]	**36**	[1; 6; 15; 18–20; 22; 24; 27–29; 31; 32; 36; 40; 44; 50–52; 56; 59; 63; 65; 67; 69; 72]
	Type (quality)	**50**	[1; 3; 6; 7; 10; 15; 18–20; 22; 24; 27–29; 31–33; 35; 36; 40; 42–44; 48; 50; 55; 56; 59; 61; 63; 65; 67–69; 71; 72]	**40**	[1; 6; 7; 15; 18; 19; 20; 22; 24; 27–29; 31; 32; 36; 40; 43; 44; 48; 50; 55; 56; 59; 61; 63; 65; 67; 69; 72]
CONTEXT	*Implementation setting*	**0**	None	**0**	–
OUTCOME	*Self-related Constructs*	**6**	[31–33; 69]	**4**	[31; 32; 69]
	Ill-Being-Well Being	**14**	[10; 18; 43; 46; 47; 56; 58; 59; 61; 72]	**10**	[18; 43; 46; 56; 59; 61; 71]
	Cognition-Brain	**33**	[1; 6; 7; 11; 15; 16; 22; 24; 26; 27; 28; 30; 35; 38; 40; 42; 50; 62; 63; 65; 66; 67; 68; 71]	**18**	[1; 6; 7; 15; 22; 24; 27; 28; 40; 50; 63; 65; 67]
STUDY	*Comparator type*	**50**	[1; 3; 6; 7; 10; 15; 18–20; 22; 24; 27–29; 31–33; 35; 36; 40; 42–44; 48; 50; 55; 56; 59; 61; 63; 65; 67–69; 71; 72]	**40**	[1; 6; 7; 15; 18; 19; 20; 22; 24; 27; 28; 29; 31; 32; 36; 40; 43; 44; 48; 50; 55; 56; 59; 61; 63; 65; 67; 69; 72]

Note. BMI = Body Mass Index. Detailed data are reported in Supplementary Material 4. §Reference codes refer to the numbered list of included studies, which can be found in Supplementary Material 2.

alters attention (i.e., focusing on certain aspects of current experience to the exclusion of others) and processing speed (i.e., time it takes to understand and do a mental task).

From comparisons between CS (boxing) practitioners with athletes from other sports inconsistent outcomes emerged [13; 17; 42], with karate practitioners' processing speed performing faster than in tennis, soccer, and volleyball players [17], boxers presenting slower visual scanning but faster information processing speed than non-boxer athletes [13], while no differences emerged in visual scanning speed [42].

Also comparisons between CS (boxing) athletes and non-athletes revealed inconsistent outcomes, suggesting that MA practice leads to faster allocation of attention and initiation of action than non-practice [26; 40; 71] or reporting null associations [16; 24; 40]. Similarly, amateur boxers showed slower reaction times and processing times than non-boxers [41], but their attentional processing speed and accuracy, and choice-reaction time performance did not differ from those of non-practitioners of CS or non-athletes [12; 38; 53].

Inconsistent outcomes emerged also in the comparisons between practitioners who differ in MA type, or in MA/CS practice duration/experience with faster perceptual processing speed in taekwondo than karate practitioners [16], but faster simple-reaction time in karateka with higher experience, whereas no difference in simple reaction time could be found comparing karateka with different skill levels [22]. At the same time, however, more experienced karateka seemed to exhibit slower choice reaction times but higher accuracy [22]. Finally, within a comparison addressing a broader variety of MA types only a weak association of expertise with alertness was revealed [40]. *C*S-based studies with boxers were also inconsistent, with a cross-sectional study reporting slower reaction time for experienced boxers [7], but a longitudinal pre-post study [37] indicating, conversely, faster processing speed in a sustained attention task.

Overall, for attention and information processing speed both consistency and strength of evidence of positive associations were limited suggestive (Table 4). Regarding moderators that may affect changes in attention or information processing engendered by MA training, transient fatigue disproportionally worsened response accuracy more in karateka than in non-athletes [23]. Neither age [50], nor handedness [4] and physical fitness [15] differentially affected processing speed (simple/choice reaction time) of athletes practicing different types of MA/CS, when contrasted among sport types or with non-athletes (Table 3).

6.3. Executive function and planning

Regarding response inhibition (i.e., interference with or prevention of a behavioural or verbal response even though the stimulus for that response is present), comparisons between MA (fencing and taekwondo) practitioners and non-athletes reported fairly consistent results of MA practice facilitating response-inhibition [11; 26; 35]. For measures of working memory, instead, no differential working memory performance emerged consistently between MC/CS (boxing, aikido, judo, and karate) practitioners and non-athletes [12; 50], or other types of athletes (multiple MA such as judo, aikido and karate with. Multiple sports such as football, running, walking, swimming, cycling [50]) and between different expertise levels within the same MA/CS (boxing [7], karate [34], fencing, judo, and wrestling [62]).

Based on neuropsychological test batteries including tests of executive function or planning (i.e., set of cognitive functions that controls complex, goal-directed thought and behaviour), no compelling evidence emerged for declines in executive function or planning as a function of boxing experience. Regarding potential moderators, similar to attention and information processing outcomes age [50; 70] and handedness [4] did not differentially affect executive function of various MA/CS practitioners compared to each other or to non-athletes. Instead, a moderating role of fitness emerged with only high-fit fencers exhibiting higher response inhibition accuracy, but not faster reaction times than similarly fit non-fencers [15]. Overall, for the executive functions both consistency and strength of evidence of positive associations were limited inconclusive (Table 4).

Table 4

Subgroup synthesis of consistency and strength of evidence of positive associations of martial arts/combat sports practice with self-related constructs, ill-being (including internalizing emotion regulation and externalizing emotion regulation), well-being, and cognition (including cognitive function, brain structure and function).

Overall	Consistency of evidence *	
	Limited suggestive (26 % of 239)	
	Strength of evidence #	
	Limited suggestive (26 % of 98)	
Mental health domain and respective subdomains	Martial arts/combat sport practitioners	
	Consistency of evidence *	Strength of evidence #
Self-related constructs	*Limited inconclusive (22 % of 23)*	*Limited inconclusive (7 % of 14)*
Self-esteem	Limited suggestive (25 % of 8)	Limited inconclusive (0 % of 6)
Perfectionism	Limited inconclusive (0 % of 5)	Limited inconclusive (0 % of 5)
Self-concept	- (50 % of 2)	–
Body image	Limited suggestive (25 % of 4)	Limited suggestive (33 % of 3)
Mindfulness	- (100 % of 1)	–
Values	Limited suggestive (33 % of 3)	–
Ill-being		
Internalizing emotion regulation	*Limited inconclusive (13 % of 23)*	*Limited inconclusive (0 % of 6)*
Anxiety	Limited suggestive (25 % of 12)	- (100 % of 1)
Depression	Limited inconclusive (0 % of 5)	- (100 % of 1)
Disordered eating	Limited inconclusive (0 % of 6)	Limited inconclusive (0 % of 4)
Externalizing emotion regulation	*Limited inconclusive (20 % of 35)*	*Limited suggestive (25 % of 4)*
Aggression	Limited inconclusive (17 % of 12)	–
Hostility	Limited inconclusive (18 % of 11)	Limited suggestive (25 % of 4)
Anger	Limited inconclusive (17 % of 12)	–
Well-being	*Limited suggestive (39 % of 23)*	*Probable (44 % of 9)*
Emotional competence/intelligence	Limited suggestive (40 % of 5)	Limited suggestive (33 % of 3)
Coping	Limited suggestive (33 % of 6)	–
Life satisfaction	- (50 % of 2)	–
Loneliness	Probable (66 % of 3)	Probable (66 % of 3)
Empathy	- (50 % of 2)	
Emotion-related mental health	- (0 % of 2)	–
Control	Limited suggestive (33 % of 3)	Limited suggestive (33 % of 3)
Cognition		
Cognitive function	*Limited suggestive (29 % of 103)*	*Limited inconclusive (23 % of 56)*
General neuro-psychological status	- (0 % 1)	–
Executive function	Limited inconclusive (20 % of 30)	Limited inconclusive (17 % of 18)

Table 4 (*continued*)

Overall	Consistency of evidence *	
	Limited suggestive (26 % of 239)	
	Strength of evidence #	
	Limited suggestive (26 % of 98)	
Mental health domain and respective subdomains	Martial arts/combat sport practitioners	
	Consistency of evidence *	Strength of evidence #
Learning and memory	Limited inconclusive (15 % of 13)	Limited inconclusive (17 % of 6)
Attention and information processing speed	Limited suggestive (31 % 48)	Limited suggestive (26 % of 23)
Intelligence	Limited suggestive (33 % of 6)	Limited inconclusive (20 % of 5)
Perception	Limited suggestive (33 % of 6)	Probable (50 % of 4)
Brain structure	*Limited inconclusive (6 % of 16)*	–
Grey matter (MRI)	Limited inconclusive (0 % of 4)	–
White matter (MRI, DTI)	Limited inconclusive (0 % of 4)	- (0 % of 1)
Cortical thickness	- (0 % of 2)	–
Cerebral spinal fluid	- (0 % of 1)	–
Total brain volume	- (0 % of 2)	–
Volume of specific brain regions	- (0 % of 1)	–
Neural viability and receptor density	- (50 % of 2)	–
Brain function	*Convincing (56 % of 16)*	*Convincing (67 % of 9)*
Brain metabolism	- (0 % of 1)	–
Brain oxygenation/perfusion	Probable (66 % of 3)	- (50 % of 2)
Electroencephalography (EEG)	Convincing (80 % of 5)	Convincing (80 % of 5)
Visual Evoked Potentials (VEPs) and Event-Related Potentials (ERPs)	Limited suggestive (42 % of 7)	- (50 % of 2)

Note. Overall findings are highlighted in italic type. *Consistency of evidence: % of samples with positive outcome(s) within the whole set of samples (n = 239), defined as 'limited inconclusive', 'limited suggestive', 'probable', 'convincing', or 'very convincing', if evidence of positive outcomes was provided by < 25 %, 25 to <50 %, 50 to <75 %, 75 % to <100 %, 100 % of the samples, respectively. #Strength of evidence: % of samples (n = 98) with positive outcome(s) within higher-quality (≤1 domain with "high risk of bias" and ≥3 domains with "low risk of bias") of studies only (n = 34). Less than three studies are considered insufficient to evaluate consistency and strength of evidence.

6.4. Learning and memory

The research is limited to practice and competition of boxing, returning inconsistent outcomes. Neuropsychological batteries that include tests of short- and long-term memory were employed in the majority of these studies.

Comparisons between boxers and team ball game and track and field athletes reported conflicting results, with boxers performing more poorly on tests that involved delayed recall (i.e., process whereby a representation of past experience is elicited) and recognition (i.e., knowledge or perception that someone or something present has been previously encountered) but outperforming team game players in serial addition [13], or with no differences [68].

Inconsistent results emerged in comparisons between boxers and non-athletes, with boxers performing worse in verbal and psychomotor learning (i.e., relatively permanent change in behaviour that is the result of past experience or practice) compared to non-boxers [38; 41], whereas selective disadvantages of boxers appeared in some memory functions (logical memory, long-term visuospatial memory) but not in

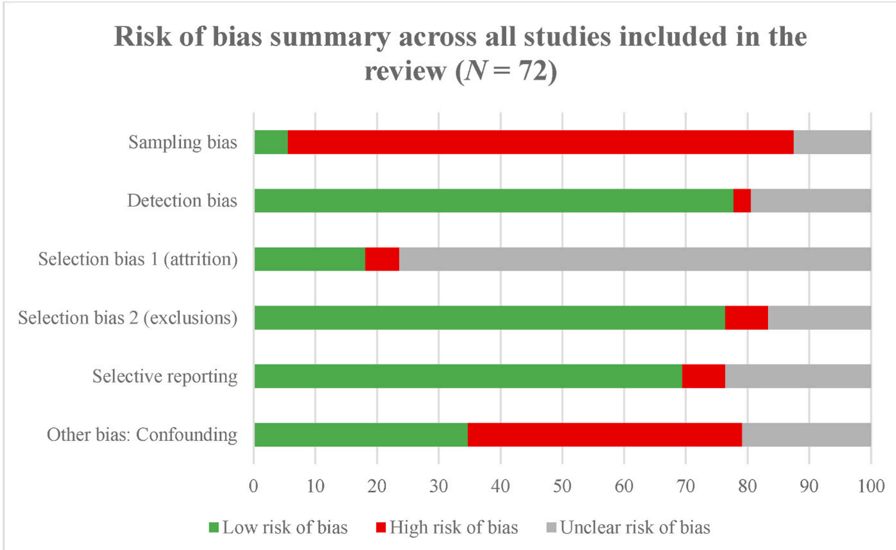

Figure 2. Risk of Bias Graph.
Note. *N*: number.

others (e.g., verbal short- and long-term memory) [5; 12]. Overall, for learning and memory (i.e., complex mental function including memorizing/learning, retention, recall, and recognition) both consistency and strength of evidence for positive associations were limited inconclusive (Table 4).

6.5. Brain structure

For brain structure (i.e., anatomical part of central nervous system contained within the cranium), grey/white matter integrity was assessed with brain structural assessments in boxers [5; 37; 38], and in a broader range of MA/CS athletes [10]. Assessments regarded total brain volume and region-specific brain volumes, cortical thickness and cerebral spinal fluid (Table 2).

As regards boxing, neither altered grey and white matter integrity compared to non-athletes [5; 37], nor longitudinal alteration over time emerged [37], but lower white matter integrity appeared [38].

For brain structural outcomes (grey matter integrity), comparisons between MA practitioners and non-athletes found no differences [10]. The absence of differences in brain structure between MA/CS and non-practitioners was further confirmed by assessing total and region-specific brain volumes [5; 10], cortical thickness and cerebral spinal fluid [5; 37]. Overall, for brain structure the consistency of evidence for positive associations was limited inconclusive, whereas the lack of sufficient higher-quality studies prevented to calculate the strength of evidence (Table 4).

6.6. Brain function

As regards brain functional outcome (i.e., complex and coordinated functional activities of the brain) measures, the most frequent assessments were Visual Evoked Potentials (VEPs) and/or Event-Related Potentials (ERPs) in karateka, fencers and judoka [24; 26; 27]. Because of the different cognitive tasks and types of stimuli used, the outcomes of comparisons between MA/CS practitioners and non-athletes [26; 27], and between MA athletes of different competition level [24] are hardly comparable.

Group differences emerged in amplitude and/or latency of specific ERP components, suggesting differential patterns of brain activation, linked to cognitive performance differences, for more complex cognitive tasks (discrimination and inhibitory go/no-go tasks, but not simple reaction time tasks [26]), for sport-specific target stimuli [24] and after been exposed to acute exercise, which acted as a moderator of group differences in brain activation [27]. Later, cognitive rather than earlier sensory components seem sensitive to group differences, with a mixed pattern of influence on their amplitude and/or latency. In the case of significant group differences, while latencies were univocally shorter in MA/CS athletes than in non-athletes, amplitudes were generally either higher in MA/CS athletes [26], or group differences were moderated by the type of stimuli, with sport-specific stimuli showing a complex pattern of smaller amplitude of some components followed by a larger amplitude of a later component both in athletes versus non-athletes and in elite versus amateur athletes [24].

Further brain electrophysiological outcome measures were electroencephalographic power and synchronization [1; 28]. They showed a pattern of higher power/synchronization in specific frequency bands and brain regions in karateka versus non-athletes and elite versus amateur karateka [1]. Lastly, abnormalities in boxers emerged on neuronal viability and brain metabolism [5] and brain perfusion [41], while for functional connectivity differential results in different brain networks appeared in fencers [35]. Overall, for brain function both consistency and strength of evidence of positive associations were convincing (Table 4).

6.7. Moderators/mediators

To address the second and third aims of this systematic review, data on multiple moderators were extracted from the retrieved studies: participant-, exposure-, context-, outcome- and study level moderators. Table 3 shows how many studies dealt with each moderator and how many reported evidence of its influence. We coded as evidence of moderation a significant statistical difference ($p < 0.05$) between subcategories of the moderator in the association between MA/CS participation and MH outcomes, as results of statistical measures (e.g., ANOVAs, correlation and regression analyses). Exposure level moderators (i.e., dose and type of MA/CS participation), as well as type of comparator and cognitive outcome domain were most frequently addressed (range: 33–50 %) and reported to have an impact (range: 18–40 %). The moderating role of age was evaluated in 31 % of studies, but confirmed in 8 % only, while expertise and sex were evaluated in 17 % and 18 % respectively, but confirmed in 10 % and 13 % of studies, respectively. Other participant level moderators were Body Mass Index, education, length of training, level of competitive engagement, and weight category. Context level (i.e., the setting where the study was implemented) moderators were never measured. Overall, moderation was addressed in a range of 3 %–54 % of the studies. No mediating mechanisms were identified.

6.8. Risk of bias

The overall evaluation of risk of bias is summarized in Figure 2, whereas study-specific risk of bias results (*n* = *72*) are available as Supplementary Material 3. A high risk of selection bias due to non-random sample selection was identified in 59 (82 %) of the studies. Conversely, the use of validated tools for capturing mental health outcomes determined a low risk of detection bias in 57 (79 %) of the studies. An unclear risk of attrition bias for 56 (78 %) of the studies was due to a lack of information on missing data. In general, non-justified exclusions from the analysis (n = 16 studies; 22 %) and selective reporting of outcomes (*n* = *19* studies; 26 %) were low, whereas only 3 studies (4 %) presented a high risk of selective reporting due to secondary data analyses. Finally, 30 studies (42 %) were judged at risk of confounding bias, as they did not control for potential confounding factors in the analyses. Among studies showing a higher (i.e., 'probable' and 'convincing') strength of evidence, those showing a significant association between MA/CS participation and positive mental health outcomes [1; 28; 43; 67] had a lower risk of detection and selection (for non-justified exclusions from the analysis and selective reporting) biases compared to the overall pool of studies, as detailed in Table 4 and Supplementary Materials 3 and 4.

7. Discussion

Encompassing 70 cross-sectional studies and two longitudinal researches, this systematic review aimed to identify associations between participation in MA and CS with measures of mental and cognitive health. Specifically, outcomes were assessed concerning self-related outcomes, emotion and well-being, cognitive functioning and brain structure and function. Associations and group differences from observational studies were reported for MA/CS participants either compared with other sports or with non-sport controls. High or unclear risk of bias was reported for three of six criteria, including high risk of bias for sampling and confounding. Overall, only a limited number (n = 26 % of consistency and strength of evidence) of significant positive associations or group differences was detected, with some aspects of cognitive functioning showing slightly stronger significant trends.

7.1. Knowledge gaps in the relationship between martial arts/combat sport and mental health

The relationship between MA/CS and mental health is a complex and multifaceted topic that has gained increasing attention in recent years with an evolving literature (Ciaccioni et al., 2021; Cooper & Lochbaum, 2022; Moore et al., 2020; Origua et al., 2017; Valdés-Badilla et al., 2021, 2022). Allowing for causal inference, intervention studies (both randomised and non-randomised controlled trials) have reported improvements in psychological and emotional aspects including reduced aggression, anxiety, and depression, enhanced mood, and self-related constructs (e.g., awareness, confidence, efficacy, and esteem) as well as increased perceptual-cognitive skills such as reaction time, motor time and processing speed (Origua et al., 2017; Oulanova, 2009; Moore et al., 2020; Russo & Ottoboni, 2019). Despite this, to expand our understanding there are several knowledge gaps that need to be addressed. Firstly, there is a lack of consensus on the definitions and measures used to assess both MA/CS and mental health outcomes, including many indicators (e.g., time of practices, frequency, training details, and duration of interventions), disorders and conditions to be considered (Fogaça et al., 2021; Russo & Ottoboni, 2019). The diverse range of MA/CS, the multiple methodologies in which they are investigated as well as the varied ways in which they are perceived, practiced and collectively shared, make it challenging to draw clear conclusions about their potential impact on mental health (An & Hong, 2018; Palumbo et al., 2023). Secondly, research on the relationship between MA/CS and mental health has primarily focused on individual experiences and outcomes (e.g., sex, age, educational status), rather than on the broader sociocultural and environmental factors (e.g., contexts, settings of MA/CS practice) that may influence mental health (Llopis-Goig, 2015; Palumbo et al., 2023). Thirdly, many scientific papers are published in languages other than English, and they may be targeted towards non-English speaking readers (Osipov et al., 2019; Rico-González et al., 2022). This can be a barrier to accessing scientific knowledge for those who do not speak the language in which the papers are published. Therefore, an effort of the academia is to consider also studies available in different languages as well as to acknowledge any language or publication type restrictions (Page et al., 2021; Rico-González et al., 2022). Lastly, whilst there is a need for more research investigating the potential risks associated with MA/CS participation (e.g., head injuries, long-term impact of physical injuries) on mental health outcomes, a broader and technology-assisted approach is also needed to examine how cognitive functioning, as well as brain structure/function, can affect the interconnected spheres of emotional, psychological and wellbeing-related health (Koutures & Demorest, 2018; Naves-Bittencourt et al., 2015; Russo & Ottoboni, 2019).

7.2. Self-related constructs

Self-related constructs included those of self-esteem and perfectionism (Fox, 2000; Stoeber & Otto, 2006). Results showed a mixed picture, with associations being limited. A contributing factor may have been that studies used a variety of measures to assess these constructs, impacting on the ability to compare and synthesize the findings across studies. In general, self-related constructs are replete with definitional and conceptual ambiguity, with key-terms often not defined consistently and studies focusing only on global construct and ignoring arguably more relevant sub-domains (Biddle et al., 2021). Considering the self-related constructs from a factorial perspective, some studies provided useful information for identifying patterns (e.g., in body esteem) across different populations (e.g., combat vs. team sports). However, this approach may oversimplify the complexity of the self and overlook individual differences in how individuals experience and understand themselves. Conversely, with a different theoretical approach feelings of global self-esteem – the typical construct addressed in the studies – is just one part of a hierarchical structure of the self (Fox, 2000). Constructs lower in the hierarchy, such as physical self-worth, were not usually addressed. It is also possible that the quality of the experience in MA or CS will be partly responsible for feelings of self-worth, and these can differ within the activities under investigation (Biddle et al., 2019). More information is required in future research concerning settings, guidance, and training loads adopted, and how participants reacted to such factors (Pesce et al., 2021).

7.3. Ill-being: internalizing and externalizing emotions regulation

Compared with other athletes, MA/CS practitioners seem to present slightly lower levels of anxiety, with results on depression being inconclusive. Conversely, in activities with weight classifications, MA/CS could be associated with disordered eating behaviours, especially in female athletes. This is in line with previous studies (Ciaccioni et al., 2019) recommending a regular monitoring of athletes at higher risk (e.g., individuals with oligomenorrhea or practicing weight-dependent sports).

Athletes taking part in MA/CS may have opportunities to experience cathartic effects of physical activity, and hence be beneficial for levels of anxiety (Moore et al., 2020). However, results were mixed and future research will need to look further into how and when anxiety is assessed relative to acute and chronic participation (Wargo et al., 2007).

Externalizing and maladaptive behaviours and emotions (e.g., aggression, hostility, anger) can be associated with mental disorders, and could be expected to be highly relevant to the MA/CS participation context (García-Sancho et al., 2014; World Health Organisation, 2019). Whilst MA have been depicted as a worthwhile intervention in reducing aggressive behaviours (Harwood et al., 2017), a recent meta-analysis showed a minimal non-significant positive effect of MA in reducing aggression in children, adolescents, and young adults (Moore et al., 2020).

We found mixed results. Karate showed lower scores for aggression than kick boxing, judo and wrestling, but compared to other sports they were higher on scores of physical aggression, though not on total and verbal aggression. Considering also that kickboxing showed higher scores of physical, total and verbal aggression than other sports, it seems that the type of MA/CS may be associated with different levels of aggression.

We found mixed results with higher levels of hostility for kickboxers when compared with other sports, but no differences for other MA/CS activities. Some of these activities may have social and ethical climates that create controlled behaviours and thus not let feelings of hostility develop. If feelings of hostility do emerge, they may become 'bracketed' within the MA/CS context. The length of training may moderate the relationship between MA/CS and hostility and this, too, could be a function of the atmosphere or climate developed over time (Harwood et al., 2017).

Finally, in the current review we found no differences in anger for most of the comparisons, with the exception of kickboxers scoring higher levels than other sport athletes and karateka. Considering that length of training and partially competitive engagement seem to be the stronger moderators of the relationship between MA/CS and externalizing emotion regulation concepts, the benefits of MA/CS on aggressive behaviours could be explained as the result of continuous and meaningful training on self-control, which is integral part of the usual MA/CS practice (Barreira, 2017).

7.4. Well-being

The constructs examined under well-being (i.e., emotional competence/intelligence, coping, life satisfaction, loneliness, empathy, emotion-related mental health, control) can be interpreted as strength-based rather than pathological/deficit-based (such as internalizing and externalizing emotion regulation) outcomes (Moore et al., 2020). While we found mixed results, with a number of construct dimensions showing no association with MA/CS participation, the dimensions that did show significant associations suggest that MA/CS participation may be related to more emotional resilience (e.g., stronger task-coping, positive reframing, assertiveness, emotional competence, and lower avoidance-oriented coping and emotional reactivity). Exposure to disciplined training and activity-specific self-control training (Biddle et al., 2021; Seitz et al., 1990) may contribute to this relationship, and it may be moderated by sex.

7.5. Cognitive functioning, and brain structure and function

Defined as mental processes that contribute to perception, memory, intellect, and action, cognitive functioning provides a core foundation upon which mental health is established (Biddle et al., 2019; Lubans et al., 2016; Taylor & Faulkner, 2008). Results from the papers addressing MA/CS and cognitive functioning showed consistent evidence of associations with perceptual and inhibition benefits, but inconsistencies for attention and memory, and with brain functional outcomes. Brain structural evidence was mostly from studies on amateur and professional boxing and these were inconclusive.

Individual studies selected for review herein target cognitive aspects considered essential for enhanced mental processing in terms of executive functions such as response inhibition, working memory/updating, and switching (Tomporowski et al., 2012). In fact, situational awareness is grounded in implicit motor learning that emerges with the repeated associations between perception and action, whereas strategy reflects the roles of higher executive functions, metacognition, and planning (Alvarez-Bueno et al., 2017). Whilst in battle, survival is often achieved by blocking emotions of fear, anger, or other intruding thoughts; therefore, contemporary teachers preparing athletes for sport competition stress the importance of training that results in automatic and reflexive-like responding (Wulf & Lewthwaite, 2016). In fact, skill acquisition is central to all MA/CS, which are characterized by specific techniques learned via instruction, modelling, and feedback from instructors, requiring years of deliberate practice.

Thirteen studies in the review examined brain structure and function in MA/CS in relation to mental health outcomes. All studies with structural brain imaging except one were performed with boxers to evaluate any negative impact of concussion on brain and cognition. Studies with functional electroencephalography were performed to investigate the positive functional adaptations of the athletes' brain to the challenges of MA.

Regarding boxing, existing evidence is limited and mostly fails to confirm the hypothesized negative brain outcomes (Butler et al., 1993; Hart et al., 2017). However, while brain hypometabolism was associated with worsened memory performance, altered neuronal viability was not. All the other studies failed to provide support to altered brain structure and function in boxers. Methodological differences and diverging foci on different brain regions linked to the cognitive or emotional health outcomes of interest do not allow for thorough comparisons.

The hypothesis that extensive practice of MA may lead to functional adaptations of the athletes' brain found some supportive evidence. The evidence suggests that ERPs have the potential to shed light onto the brain activation mechanisms that underlie complex cognitive performance in MA/CS practitioners also when behavioural outcome measures are not sufficiently sensitive to detect group differences (e.g., Del Percio et al., 2007).

MA/CS athletes, compared to non-practitioners or less skilled MA/CS counterparts, seemed to employ more efficient strategies ranging from an earlier onset of specific stages of information processing (i.e., shorter latency of the corresponding ERP component [Drapsin et al., 2012]) to a larger allocation of resources in specific stages (i.e., larger amplitude of corresponding ERP components [Di Russo et al., 2006]), or a differential distribution of resources in different stages (smaller at earlier and larger at later stages [Del Percio et al., 2007]). Also, MA/CS athletes seem better able to modulate brain activity in response to sport-specific stimuli (Del Percio et al., 2007) and with physical (Drapsin et al., 2012) or mental workload conditions (Duru & Assem, 2017) which are inherent in MA/CS practice. This limited, but promising, evidence calls for further research that moves from cognitive sport psychology to mental health and physical activity research.

7.6. Strengths and limitations

The fact that we searched articles in different languages from a large number of electronic databases and reference lists of included articles gives this review a distinct advantage. However, due to limited available linguistic resources we need to acknowledge the impossibility of including literature published in other languages, which could potentially impact on the generalizability of our findings considering the strong MA history of many regions (Buckler, 2016; Martínková & Parry, 2016). Within a broader timeframe compared to those applied to other fields (e.g., medicine, public health), we chose to include studies from as early as 1965 to provide a comprehensive overview of the available literature on our topic, and to explore how research in this area has developed over time. While the number of related studies published prior to the 1990s is relatively small, including older valuable studies was deemed important to fully capture the historical context and evolution of research in this field. Moreover, the PRISMA guidelines for the conduct and reporting of systematic reviews were carefully followed. Two researchers independently carried out the different stages of the review process (screening, data extraction, risk of bias assessment). Some limitations must also be acknowledged for our review. Many of the included studies did not report sufficient information regarding the training guidance provided, such as details on programs, delivery modes, and instructors. Whilst this lack of information may hinder the ability to draw conclusive results regarding the relationship between MA/CS and MH, the related variability may also influence the efficacy of interventions being evaluated, leading to inaccurate estimations of effects and generalizability of findings, and difficulty in replicating interventions for practitioners and researchers. Searches were restricted to published studies, which may have resulted in missing relevant literature. In addition, following the methodology described by Sallis et al. (2000), only the statistical significance and direction between MA/CS participation and a given mental health variable was coded, excluding its magnitude of association. Future reviewers should consider whether extracting data on the size of the associations is meaningful and how to embed this additional information within current and widely accepted methodologies for the study of correlates (e.g., Sallis et al., 2000). In our case, a quantitative synthesis (meta-analysis) was deemed inappropriate due to the heterogeneity of mental health measures employed and the limited number of studies investigating the same associations. Finally, as described by Sir Austin Bradford Hill (Hill, 1965) the assessment of causality requires appraisal of the evidence on a number of criteria (e.g., strength of association, consistency, temporal sequencing, coherence and biological plausibility, dose-response association, and experimental evidence). On the basis of the retrieved data from cross-sectional and only two longitudinal studies, it was not possible to identify conclusive causal connection.

Nevertheless, multiple moderator mechanisms intervene within the association between MA/CS participation and MH outcomes at different levels. In particular, they own a significant role at participant-, exposure-, outcome- and study-level, but the retrieved studies neglected the context-level moderators. Although the literature suggests many types of mediating mechanisms (genetic, neuro-biochemical, neurophysiological, behavioural, environmental factors) intervening in the relationship between physical activity and mental health outcomes (Pesce et al., 2021), the included studies did not address potential mediating mechanisms.

8. Directions to strengthen future research

In relation to the risk of bias for included studies, sampling methods and confounding were identified as important sources of bias and deserve special attention in future studies. Using random sampling (e.g., probability sampling, multistage sampling) and statistical methods to control for confounding effects (e.g., stratification, multivariate models) will help strengthen the available evidence. In addition, many studies were coded as having an unclear risk of attrition bias. Authors can minimise incomplete reporting by using standardised reporting guidelines (e.g., STROBE statement for observational studies; Von Elm et al., 2007). Related to reporting, sample description could also be improved as key information such as details of study setting, guidance, sex of participants, expertise in MA/CS (in years), competitive level, training load (e.g., volume, intensity, velocity of movements), and instructor's experience were often missing. Beyond reporting, thoughtful selection and justification of comparison groups is also important. If comparison groups are also physically active, this could reduce the effect size of mental health outcome comparisons. On the other hand, considered selection of other sports groups may allow conclusions about specific effects of the structure of MA/CS training. Reporting and designing issues in MA studies in general might benefit from the development of MA specific reporting guidelines, perhaps along the lines of those recently provided for holistic movement practices (Vergeer et al., 2023).

Future research should assess whether each studied mental health outcome can be considered to be causally associated with MA/CS participation (Hill, 1965). To note, among the studies with a higher strength of evidence, the limited number of observational studies providing preliminary support for improved mental health in MA/CS practitioners presented a lower risk of bias compared to the larger number of studies that could not demonstrate a positive association between MA/CS practice and mental health outcomes. Thus, improvements in designing and reporting upcoming studies should contribute to strengthening the available evidence, which will benefit future reviewing efforts. Finally, whilst some sports categories (e.g., team sports, aquatic sports, winter sports, combat sports) present common aspects, disciplines within a given category often exhibit specific characteristics that differentiate them from each other. Thus, the generally inconclusive results of the present study could be due to extensive methodological heterogeneity among the considered disciplines, urging further investigations specifically related to a sport discipline or sub-categories sharing common features.

9. Conclusion

MA and CS have the potential to benefit different aspects of mental health. This systematic review shows that participation in MA/CS is associated with benefits in some components of mental health, including visuospatial perception, response inhibition, externalizing emotion regulation, and coping skills, but inconsistent, conflicting, or null findings for anxiety, self-related characteristics, depression, attention, learning, memory, planning, and brain structural changes. Moreover, the mechanisms underlying the relationship between MA/CS practice and mental health, and the role of moderators are not completely understood. This review suggests that some brain functional methods such as ERPs/VEPs can be used to shed light on the neural mechanisms underlying complex cognitive functions in MA/CS practitioners, employing more efficient strategies by MA/CS practitioners compared to non-athletes or less-skilled MA/CS athletes. Among different studied variables, only the moderating effect of physical fitness on MA/CS-response inhibition has been demonstrated. It seems that the lack of clear or exhaustive information on modalities of MA/CS education/practice, as well as on the role of instructors and interpersonal factors (Diamond & Ling, 2020) might be responsible for the inconsistent results. Through their universal appeal and many sport-related, philosophical and ethical grounds, MA/CS may influence the complexity of mental health. Still, future research needs to identify the underlying mechanisms and causal processes linking the different outcomes domains. Overall, we concur with a recent call for answering to what extent and in what way different forms and contexts of physical activity contribute to mental well-being, for different conditions or populations (Vergeer & Biddle, 2021).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

This review did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors. Simone Ciaccioni is presently funded by the European Commission through the Erasmus+ Sport programme (Project Reference: 622155-EPP-1-2020-1-IT-SPO-SCP). We acknowledge Daphne Schmid for the drafting support.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2023.102556.

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