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Original article

Physical activity interventions can improve emotion regulation and dimensions of empathy in persons with multiple sclerosis: An exploratory study

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ABSTRACT

Background: Persons with multiple sclerosis (PwMS) report difficulties with emotion regulation and empathy. Regular physical activity (RPA) improves dimensions of psychological well-being in PwMS, but it remains unclear if regular physical activity has effects on emotion regulation and empathy. The present study investigated the effect of regular physical activity on emotion regulation and empathy, and explored, if endurance training or coordinative training are better than an active control condition.
Methods: 92 female PwMS (mean age: 37.4 years; age range: 20–57 years; mean EDSS: 2.43) took part in this study. Participants were randomly assigned into endurance training, coordinative training, or active control conditions that all lasted 8 weeks and were yoked on frequency, duration, and social contact. Participants completed questionnaires on emotion regulation, empathy, depression and fatigue before and after the 8-week conditions.
Results: Regulation and control of emotions and empathy improved over time, but more so in the exercising groups, compared to the active control group. No changes over time and between groups were observed for perception and acknowledgement of emotions, emotional expressivity, and empathy, as measured with Reading in the Eyes test. These changes were not influenced by control for depression and fatigue as covariates.
Conclusions: Both endurance and coordinative exercise training had favorable effects on some aspects of emotion regulation and social cognition such as empathy in PwMS. Such initial results support for examination of exercise training for the treatment of issues of emotion regulation and social interactions in PwMS.

1. Introduction

Multiple sclerosis (MS) is a common chronic inflammatory degenerative autoimmune disease of the central nervous system (Reich et al., 2018; Thompson et al., 2018), and more than 2 million people worldwide are affected with this disease (Reich et al., 2018). Typically, persons with MS (PwMS) report both physical and psychological symptoms and impairments (Alghwiri et al., 2018). Physical complaints include visual impairments, fatigue (sensations of physical lassitude), limb weakness, paresthesia, sensory loss, or impairments of gross and fine motor skills (Reich et al., 2018; Thompson et al., 2018). Psychological complaints involve symptoms of cognitive impairments (Benedict and Zivadinov, 2011; Benedict et al., 2017), depression (Amtmann et al., 2015; Barzegar et al., 2018; Berzins et al., 2017; Boeschoten et al., 2017), sleep disturbances (Kallweit et al., 2018; Kallweit et al., 2013; Braley, 2018; Veauthier et al., 2016; Veauthier and Paul, 2014; Sadeghi Bahmani et al., 2019). These problems often coincide with modification (Sadeghi Bahmani et al., 2018)

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or decrease in physical activity levels (Latimer-Cheung et al., 2013; Motl et al., 2017; Pilutti et al., 2014; Platta et al., 2016; Motl et al., 2012; Veldhuijzen van Zanten et al., 2016), and emotional and social impairments (see below for more details) (Chalah and Ayache, 2017; Cotter et al., 2016; Phillips et al., 2014; Phillips et al., 2009).

To date, there is research supporting the favorable influence of regular physical activity on psychological well-being, including depression, fatigue, paresthesia (Latimer-Cheung et al., 2013; Motl et al., 2017; Pilutti et al., 2014; Platta et al., 2016; Razazian et al., 2016; Sandroff et al., 2016), and subjective and objective sleep quality (Sadeghi Bahmani et al., 2019; Sadeghi Bahmani et al., 2019) among PwMS. To illustrate, in a previous publication (Sadeghi Bahmani et al., 2019) we showed that compared to an active control condition, both endurance and coordinative training improved sleep complaints and symptoms of depression, while no improvements were observed for fatigue, paresthesia, and intolerance of uncertainty. However, to our knowledge, research on the influence of regular physical activity on emotion regulation, social competences, and social cognition is scarce. This is surprising, if we consider that following the science of evolutionary psychology (Dunbar, 2009; Dunbar, 2012), our brain evolved and increased to its current dimensions and complexity to cope with social environments, including complex interaction information processing (Cosmides et al., 2005).

Social competences and social cognition are understood as the ability to infer the intentions, dispositions, and beliefs of other persons (Phillips et al., 2014; Phillips et al., 2009), whereas emotional regulation is understood as the ability to perceive, regulate, and express one's own emotions appropriately, and to perceive the emotions of others correctly (Pfeifer and Blakemore, 2012; Adolphs, 2003; Rindermann, 2009). Empathy is understood as the ability to recognize emotions that are being experienced by another person (Decety and Jackson, 2004; Decety et al., 2009), and to share another person's emotions (Sucksmith et al., 2013).

Social and emotional competencies are highly intertwined and particularly important in coping with the social environment. To illustrate, Visted et al. (2018) speculated that among individuals with a history of major depressive disorders, poor emotion regulation and lower social competencies might be a latent risk factor for relapses. Moreover, functional deficits in emotion processing and the respective response selection have been associated with poor social functioning (Marsh and Blair, 2008). In the same vein, impairments in emotion processing have been associated with difficulties in building up relationships, resulting in rejection by peers and/or in solitary play, at least in children (Marryat et al., 2014). Further, among adolescents, Ding et al. (2018) underlined that perceived chronic social adversities may lead to symptoms of stress, along with depression and anxiety.

As regards emotional competences and social cognition in PwMS, Cotter et al. (2016) performed a systematic review and meta-analysis and compared 722 PwMS with 635 healthy controls. Compared to healthy controls, PwMS had more deficits in facial emotion recognition and dimensions of empathy (Cotter et al., 2016). Further, deficits in social cognition were not as severe as those identified in individuals with schizophrenia or in other neurodegenerative disorders such as Parkinson's Disease, but worse than those reported in individuals with attention-deficit/hyperactivity disorders (ADHD) or with major depressive disorders. Similarly, Chalah and Ayache (2017) summarized in their review that deficits in social cognition appeared to be highly under recognized in PwMS, and that such scarce attention is astonishing, given that poor social cognition is associated with deficits in personal interactions and relationships. Chalah and Ayache (2017) further mentioned that little attention has been paid so far on social cognition in PwMS.

Phillips et al. (2009) investigated the associations between attentional lapses and failures to use effective emotion regulation on quality of life in PwMS, and showed that both a higher rate of attentional lapses and failures in emotion regulation predicted lower scores of quality of life. Further, Phillips et al. (2014) showed that compared to 31 age- and gender-matched healthy controls, 31 PwMS reported more difficulties in emotion regulation and lower scores of quality of life. Phillips et al. (2014) further showed that symptoms of depression mediated the associations between poor emotion regulation and poor quality of life. We took this result into consideration and assessed symptoms of depression and fatigue as possible confounders.

Given the importance of emotion regulation and social cognition, surprisingly, research on the influence of regular physical activity or single bouts of physical activity on emotion regulation and social competences is scarce, and there in none in PwMS. Brand et al. (2018) reported that a single intervention of physical activity improved the interests on social interaction, understood as a proxy of social competence among individuals with psychiatric issues. Brand et al. (2019) further reported that a single bout of physical activity, compared to a control condition, altered facial emotion recognition, understood as a proxy of social competences, among healthy adolescents. To our knowledge, this was the very first study to show the direct influence of physical activity on emotion processing and social cognition. While the Brand et al. (2019) had no direct evidence of the underlying psychophysiological processes to explain the direct influence of physical activity on emotion processing and social cognition, they speculated that perhaps more efficient cognitive-emotional processes in the prefrontal cortex (PFC) could be responsible for such a result (see also more details in the Discussion section).

To summarize, there is some research on dimensions of emotion regulation and social cognition in PwMS (Chalah and Ayache, 2017; Cotter et al., 2016; Phillips et al., 2014; Phillips et al., 2009) though it is surprising to see the small research efforts, if it is considered that emotion regulation and social cognition are tightly related to quality of life and interpersonal relationships. Further, as mentioned, while there is extant research that acute and regular physical activity favorably impact on cognitive processes such as attention and further dimensions of executive functions (Ludyga et al., 2017; Ludyga et al., 2018a, b; Pesce, 2012; Best, 2010; Carson et al., 2016; Shields et al., 2016; van Uffelen et al., 2008; Voss et al., 2013) research on the impact of acute and regular physical activity on emotion recognition and social cognition is scarce for healthy samples and non-existent for PwMS. Accordingly, the aims of the present study were to fill these gaps of knowledge and to investigate a possible new avenue to improve emotion regulation and social cognition in PwMS. The research question was if, and if so, to what extent two types of regular physical activity (endurance training; coordinative training) improve emotion regulation and empathy in PwMS, compared to an active control condition.

2. Methods

2.1. Procedures

A total of 145 female PwMS of the MS Society of Kermanshah province, located in the Farabi University-Hospital of the Kermanshah University of Medical Sciences (KUMS; Kermanshah, Iran) were approached to participate in the present intervention study. Eligible participants were fully informed about the aims of the study and the confidential nature of the data handling. Thereafter, participants signed the written informed consent. Next, participants were randomly assigned either to endurance training (ET), coordinative training (CT), or to an active control condition (ACC). At baseline, and eight weeks later at the end of study, participants completed questionnaires covering emotion regulation, empathy, and depression and fatigue (see below). Experts rated participants' degree of impairment with the Expanded Disability Status Scale (EDSS) (Kurtzke, 1983). Irrespective from the study conditions, sessions took place 3 times/week for about 45–60 min for eight consecutive weeks. The ethical committee of the Kermanshah University of Medical Sciences (KUMS; Kermanshah, Iran; IRCT 2016062423705N4;www.irct.ir; KUMS.REC.1395.127) approved the

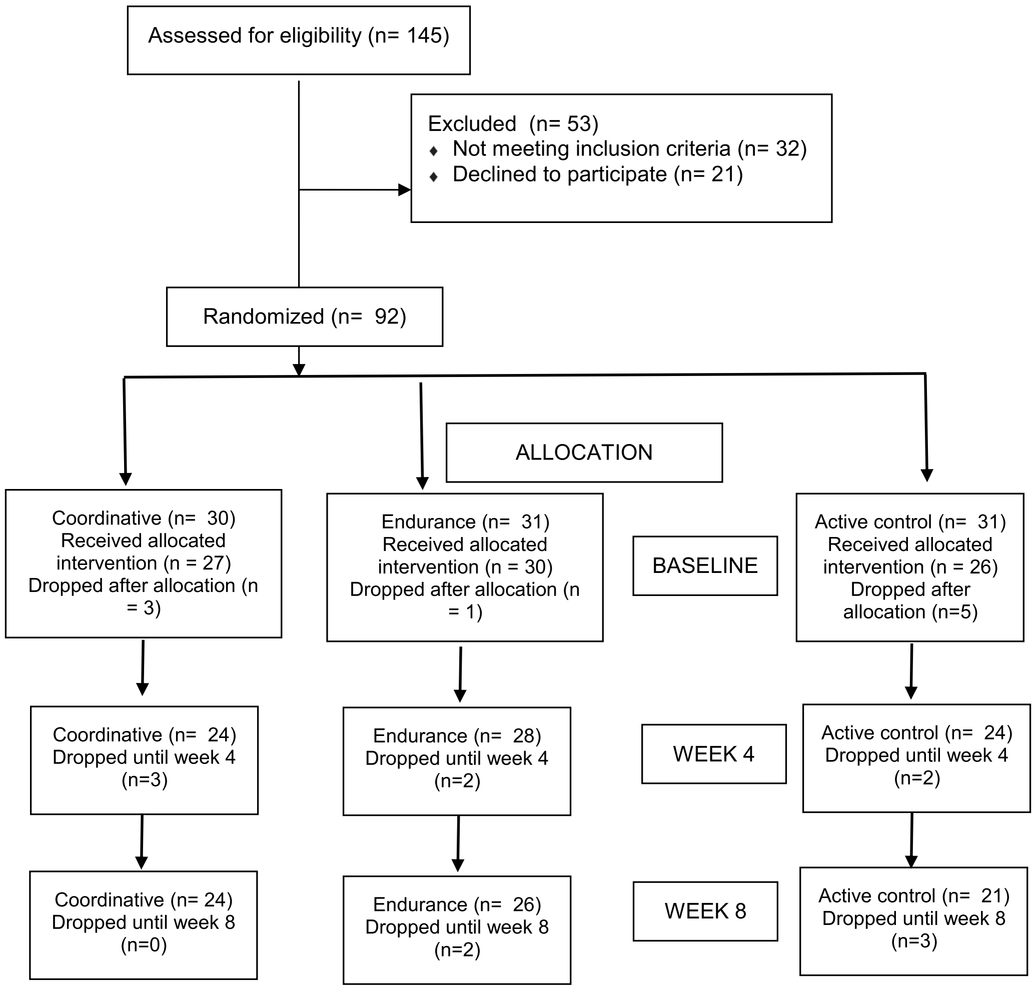

Fig. 1. Recruitment, eligibility, randomization, patients' group assignments, and number of patients per group at baseline, week 4 and week 8.

study, which was performed in accordance with the ethical principles laid down in the seventh and current edition (2013) of the Declaration of Helsinki.

The present data are part of an ongoing larger study on the impact of regular physical activity interventions on physical and psychological well-being in PwMS (Sadeghi Bahmani et al., 2019), though, the present data are novel.

2.2. Participants

A total of 92 female PwMS were consecutively enrolled in the study. Fig. 1 is the CONSORT flow chart and shows the number of assessed participants, the number of included and excluded participants, along with the number of randomized, allocated, and analyzed participants. Inclusion criteria were: 1. Age between 18 and 65 years; 2. Status of MS, as ascertained by a trained neurologist and based on Mc Donald's criteria; 3. EDSS score < 6; 4. Willing and able to comply with the study conditions; 5. Signed written informed consent. Exclusion criteria were: 1. Other neurological disease; 2. Severe psychiatric comorbidities based on a clinical psychiatric interview (Sheehan et al., 1998); 3. Acute suicidality; 4. Musculoskeletal issues which did not allow regular PA; 5. Participants withdraw from the study more than 3 sessions; 6. The principle investigator excluded participants from the study, if a participant showed adverse events, which might have been associated with the interventions. 7. Undergoing further PA, psychotherapy, or undergoing surgery; 8. Pregnancy and/or breast feeding.

We have excluded women who were pregnant, as changes in hormones, and sleep and physical activity patterns could have biased the present pattern of results (cf. Jahangard et al., 2019). Further, even though the physical activity interventions were safe and easy to comply, we did not want to risk accidents and injuries to the expecting mother and her unborn baby. Similarly, we excluded breastfeeding women, as breastfeeding mothers might have had irregular sleep-wake and physical activity patterns.

No sample size calculation was performed for the current explorative study and its outcomes, and the sample size was defined in the previous study (Sadeghi Bahmani et al., 2019).

2.2.1. Randomization

Randomization occurred with the software randomization.com. Based on this list, a psychologist not otherwise involved in the study prepared 3×15 envelops with the specific study conditions. Envelops were sealed, with no further identification, put in an opaque and closed ballot box and stirred. Next, the responsible drew an envelope and assigned participants to one of the three study conditions. Once an envelope was drawn, it was put aside. Fig. 1 shows the CONSORT flowchart of participants' study allocations. Randomization occurred after the initial assessment.

2.3. Tools

2.3.1. Sociodemographic and MS-related information

Participants reported age, and MS-related information such as duration of MS and medication regimen were obtained from medical records.

Experts rating participants' EDSS scores were blind to participants' study condition assignments.

2.3.2. Emotion regulation

As already described elsewhere (Brand et al., 2016), to assess emotion regulation, we used the Emotionale–Kompetenz–Fragebogen (emotional competencies inventory (Rindermann, 2009)). The Farsi version has been translated and psychometric properties were satisfactory (Jahangard et al., 2018). The inventory consists of 62 items and assesses the following four dimensions: (a) perception and acknowledgement of own emotions ("Sometimes I feel sad without knowing why"); (b) regulation and control of own emotions ("When I feel myself getting angry, I know how to cool down again"); (c) emotional expressivity ("I can express my feelings very well"); and (d) perception of others' emotions ("I can perceive and describe my friends' emotions very well"). Answers are on five-point Likert scales from 1 (never/not at all true) to 5 (practically always/definitely true). Higher scores reflect a higher position on each of the dimensions described above. The overall score reflects general competency in emotion regulation (Cronbach's alpha = 0.87).

2.3.3. Empathy

To assess empathy, that is, the ability to imagine what another person is currently feeling and thinking, the Reading the Mind in the Eyes (RME) test was applied (Baron-Cohen et al., 2001). The Farsi version has been translated, and psychometric properties were satisfactory (Khorashad et al., 2015). Briefly, the test consists of 36 vignettes showing the eye region in black-and-white. The rationale underlying the test is that people preferentially attend to the eyes and extract complex meaning from them as salient cues in human social communication and social categorization (Emery, 2000; Zebrowitz et al., 2006). Every vignette has four alternative descriptors of what the person in the vignette might be thinking or feeling. Each vignette is presented separately, and participants have to choose among the four descriptors. For every correct answer, one point is given; the maximum score is 36 points. Vignettes are also divided into pleasant mental states ($n = 26$; e.g., playful, friendly, fantasizing) and unpleasant mental states ($n = 10$; e.g., distrustful, preoccupied, hostile; Cronbach's alpha = 0.79).

2.3.4. Depressive symptoms

To assess symptoms of depression, we used the Beck Depression Inventory-Fast Screen (BDI-FS) (Benedict et al., 2003). The BDI-FS is a brief self-report inventory designed to evaluate depression in patients with medical illness. It consists of seven items, and every item has a set of four possible responses, representing different levels of symptom severity (e.g., or sadness: 0 = "I don't feel sad"; 1 = "I feel sad"; 2 = "I'm sad all the time and I can't snap out of it". 3 = "I'm so sad/unhappy, that I can't stand it"). Higher scores reflect a greater severity of depressive symptoms (range:0–21). Cronbach's alpha = 0.87.

2.3.5. Fatigue

To assess the level of fatigue, participants completed the Fatigue Severity Scale (FSS Krupp et al., 1989). The FSS consists of nine items, and answers are given on 7-point rating scales ranging from 1 (=not at all) to 7 (=definitively/almost always), with higher scores reflecting higher levels of fatigue. Cronbach's alpha=0.91.

2.4. Interventions

2.4.1. Endurance training

As previously described (Sadeghi Bahmani et al., 2019), endurance training condition lasted for eight consecutive weeks and consisted of three weekly supervised, guided group sessions per week. The sessions lasted 30–45 min in duration. After 5 min of warming-up and stretching, participants exercised for 25–35 min on treadmill, exercise bicycles or walking/jogging overground. Participants were encouraged to keep the pace during the intervention, though, they were allowed to pause individually for 1–2 min. After the intervention, it followed a cooling down of 5 min. At the end of a session, participants should have had the feeling to be slightly exhausted, but not severely exhausted (4–6 points of intensity on the Borg scale (Borg, 1998)). Professional instructors monitored the sessions and participants' level of performance and exhaustion.

2.4.2. Coordinative training

As previously described (Sadeghi Bahmani et al., 2019), coordinative training consisted of three supervised, guided group sessions per week for eight weeks. The sessions lasted 30–45 min in duration. After 5 min of warming up, exercises focused on CT such as balancing on a small bar, mirroring and imitating movements of others (such as dancing steps), balancing balls, 'football-tennis', balancing with closed eyes on a rope on the floor and similar exercises. The CT required a higher level of object control and locomotor skills as well as interactions with other participants. Such exercise characteristics are suggested to increase coordinative demands and cognitive engagement (Pesce, 2012; Best, 2010). At the end of a session, participants should have had the feeling to be slightly exhausted, but not severely exhausted (4–6 points of intensity on the Borg scale (Borg, 1998)). Professional instructors monitored the sessions and level of performance and exhaustion. Cooling down lasted for about 5 min.

2.4.3. Active control condition (ACC)

As previously described (Sadeghi Bahmani et al., 2019), for eight consecutive weeks, participants of the ACC met three times/week for 30–45 min/session at the hospital center to ensure that frequency, duration, and the degree social contacts of the control condition were identical to the endurance and resistance training conditions. The control condition was not a 'bona fide' psychotherapeutic intervention, which would have been actually intended to elicit change (Goyal et al., 2014; Wampold et al., 1997; Jasbi et al., 2018). Most importantly, in the control condition, topics such as successful coping strategies were not treated and not proactively proposed by the clinical psychologist responsible to monitor the content of the control conditions. Rather, participants were encouraged to proposing and exchanging daily experiences (Sadeghi Bahmani et al., 2019).

2.5. Statistical analysis

Data were analyzed per protocol. We first compared study completers and study non-completers on as regards socio-demographic, illness-related and psychological dimensions, using a series of *t*-tests and χ^2-tests. We then compared initial differences in sociodemographic data between the three groups using a series of χ^2-tests. We examined changes over time between groups using a series of mixed factor ANCOVAs on emotion regulation and empathy as dependent variables. The mixed factors were Time (baseline, week 8) and Group (ET, CT, ACC), and depression and fatigue were covariates. The nominal level of significance was set at alpha < 05. Effect sizes for F-statistics were reported as partial eta squared (ηp^2), with $0.01 < \eta p^2 < 0.059$ indicating small [S], $0.06 < \eta p^2 < 0.139$ indicating medium [M], and $\eta p^2 \geq 0.14$ indicating large [L] effect sizes. Cohen's d effect sizes were reported for the pre-post change within each of the three groups, and effect sizes were reported with Cohen's d (Cohen, 1988) values ranges: ds 0–0.19: trivial effect sizes; ds 0.20–0.49: small effect sizes; ds: 0.50–0.79: medium effect sizes; ds: 0.80 and greater: large effect sizes. Statistical analyses were performed with SPSS® 25.0 (IBM Corporation, Armonk NY, USA) for Apple Mac®.

Table 1
Sociodemographic and clinical data of participants, separately for participants in the coordination, the workout and the active control condition.

Dimensions	Groups Coordination	Workout	Active control
N	24	26	21
	M (SD)	M (SD)	M (SD)
Age (years)	39.17 (8.66)	37.96 (8.69)	37.90 (9.91)
EDSS	3.38 (1.87)	2.46 (1.50)	2.02 (1.84)
Disease duration (years)	8.13 (6.37)	6.92 (6.81)	7.21 (6.57)
	n/n	n/n	n/n
Civil status (married/single)	12/12	20/6	15/6
Highest educational level (high school/higher education)	19/5	20/6	17/4

Notes: EDSS = Expanded Disability Status Scale.

3. Results

3.1. Completers and non-completers

Completers ($n = 71$) and non-completers ($n = 21$) did not differ in age, EDSS, emotion regulation, empathy, depression, or fatigue (all t's < 1.2, p's > 0.42).

3.2. Sociodemographic and MS-related information

Participants in the three groups did not descriptively nor statistically initially differ in age, civil status, and educational level (F and all χ^2-tests < 1.00, p's > 0.50). There was a significant Group effect on EDSS ($F(2, 70) = 3.62$, $p = .032$). The post-hoc analysis indicated that participants in the coordinative condition had higher EDSS scores than participants in the ACC (Table 1).

3.3. Emotion regulation and empathy

Tables 2–4 report the descriptive and inferential statistical indices regarding group by time interactions and main effects on emotion regulation and empathy (Reading the Mind in the Eyes) measures.

Regulation and control of emotions, and empathy improved over time, but more so in the two physical activity intervention conditions, compared to the active control condition (significant interactions with medium effect size).

For Perception and Acknowledgment of emotions, Emotional expressivity, and for empathy, as assessed with the Reading the Mind in the Eyes test, no statistical or descriptive mean differences between the three study conditions and over time were observed. Note that all statistical procedures were performed controlling for symptoms of depression and fatigue.

Single effect size calculations further confirmed that dimensions of Regulation and Control of emotions and Empathy increased in the endurance training and coordinative training condition, but not in the active control condition.

4. Discussion

The key findings of the present study were that both endurance and coordinative training lasting for eight weeks improved dimensions of emotion regulation and empathy, compared to an active control condition, and even, when controlling for symptoms of depression and fatigue among a sample of female PwMS. The present study adds in an important way to the sparse research on the influence of regular physical activity on dimensions of emotion regulation and social cognition in PwMS.

This was an exploratory study and no hypotheses were formulated a priori, but the data analyses indicated that regular physical activity might have the power to favorably influence dimensions of emotion regulation and empathy. However, as shown in Tables 2–4 improvements were only observed in the dimensions of regulation and control of emotions and empathy. By contrast, no statistically or descriptively significant mean differences were observed for perception and acknowledgement and emotional expressivity, and for Empathy, as measured with the Reading the Mind in the Eyes test.

Thus, while for the very first time, we were able to show *that* regular physical activity improved some, but not all dimensions of emotion regulation and empathy as a proxy of social cognition, the quality of the data does not allow a deeper understanding, as to *why* this happened. For want of data, we advance the following explanations:

First, Brand et al. (2018) showed among a sample of inpatients with psychiatric issues that already single bouts of physical activity interventions reduced rumination and increased the interest on social interactions. Next, the intervention of 35 min of moderate exercising improved the performance of facial emotion recognition, compared to a passive control condition, at least among a sample of healthy adolescents (Brand et al., 2019).

Overall, these studies suggest that emotional information processing appear to favorably improve both after a single bout of exercising or after regular physical activity. Likewise, we speculate that similar emotional processes occurred also in female PwMS of the present study. Importantly, statistical comparisons of changes of emotion regulation and empathy from baseline to the end of the study were statistically controlled for symptoms of depression and fatigue; in doing so, we avoided that possible improvements in emotion regulation and social cognition would have been associated with improvements in depression and fatigue. In this regard, there is some evidence that regular physical activity improved symptoms of depression and fatigue in PwMS

Table 2
Descriptive statistics of dimensions of emotion regulation and empathy, separately for the two time points (baseline; week 6/study end) for the three study conditions (endurance training; coordinative training; active control condition).

Groups/study conditions	Groups Endurance training		Coordinative training		Active control condition	
Time points	Baseline	Study end	Baseline	Study end	Baseline	Study end
N	26	26	24	24	21	21
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Emotion regulation						
Perception and Acknowledgement	46.19 (8.42)	47.50 (8.81)	47.68 (14.62)	48.00 (11.55)	47.48 (10.35)	48.29 (6.19)
Regulation and Control	37.16 (9.47)	40.23 (9.53)	37.67 (11.42)	40.67 (9.87)	37.38 (8.33)	36.91 (8.97)
Emotional Expressivity	40.50 (7.28)	39.73 (8.15)	39.87 (11.18)	40.00 (7.28)	41.62 (10.35)	42.24 (8.37)
Empathy	31.50 (6.74)	34.97 (6.40)	33.46 (9.29)	37.71 (9.04)	37.67 (12.18)	37.00 (8.75)
Reading the Mind in the Eyes						
Total score	17.28 (5.08)	17.76 (5.61)	15.29 (5.39)	16.54 (4.99)	16.38 (4.28)	15.67 (4.03)
Positive emotions	5.00 (1.83)	4.20 (1.61)	4.71 (1.99)	4.33 (1.88)	4.43 (1.91)	4.29 (1.93)
Negative emotions	13.08 (4.11)	12.76 (4.44)	11.33 (3.76)	11.83 (3.95)	12.09 (3.45)	11.24 (2.88)

Table 3
Inferential statistical indices: overview of dimensions of emotion regulation.

	Factors Time F	Partial eta^2	Group F	Partial eta^2	Time by Group interaction F	Partial eta^2
Degrees of freedom	1, 66		1, 66		2, 66	
Emotion regulation						
Perception and Acknowledgement	0.69	.010 [S]	0.46	.014 [S]	0.66	.002 [T]
Regulation and Control	13.52***	.166 [L]	0.28	.008 [T]	5.04**	.129 [M]
Emotional Expressivity	0.03	.000 [T]	1.23	.035 [M]	1.23	.035 [S]
Empathy	5.65*	.078 [M]	1.55	.023 [S]	2.99*	.071 [M]
Reading the Mind in the Eyes						
Total score	0.31	.005 [T]	1.07	.031 [S]	0.85	.025 [S]
Positive emotions	2.99	.049 [S]	0.12	.004 [T]	0.96	.028 [S]
Negative emotions	0.20	.003 [T]	1.34	.038 [S]	0.45	.017 [S]

Notes: Statistics always controlling for symptoms of depression and symptoms of fatigue. * = $p < .05$; ** = $p < .01$; *** = $p < .001$. [T] = trivial effect size; [S] = small effect size; [M] = medium effect size; [L] = large effect size.

Table 4
Effect sizes for mean comparisons (emotion regulation: Perception and Acknowledgement; Regulation and Control; Emotional Expressivity; Empathy; Reading the mind in the eyes/Empathy; positive and negative emotions) from baseline to the study end, separately for the three groups (workout and coordination, and active control groups).

	Groups Endurance training	Coordinative training	Active control condition
Cohen's d's: Baseline vs. study end			
Emotion regulation			
Perception and Acknowledgement	0.15 (T)	0.02 (T)	0.08 (T)
Regulation and Control	0.52 (M)	0.50 (M)	0.05 (T)
Emotional Expressivity	0.10 (T)	0.01 (T)	0.07 (T)
Empathy	0.52 (M)	0.51 (M)	0.06 (T)
Reading the Mind in the Eyes			
Total score	0.09 (T)	0.24 (S)	0.17 (T)
Positive emotions	0.46 (S)	0.09 (T)	0.07 (T)
Negative emotions	0.07 (T)	0.13 (T)	0.28 (S)

Notes: (T) = trivial effect size; (S) = small effect size; (M) = medium effect size.

(Sadeghi Bahmani et al., 2019; Razazian et al., 2016).

Second, there is substantive evidence showing that (acute) exercise enhances performance on tasks that rely on the prefrontal cortex, such as those that involve executive functions (Ludyga et al., 2016). Given that the prefrontal cortex plays an important role in emotion processing (Etkin et al., 2011), it seems reasonable to suggest that exercise-induced improvements might be due to favorable activation patterns within this region (Fumoto et al., 2010). Likewise, it can be supposed that in the present study, dimensions of emotion regulation and empathy were associated with such improved cognitive processes, although this does not explain why such improvements were not observed for perception and acknowledgement, emotional expressivity, and empathy, as assessed with the Reading the Mind in the Eyes-test. However, in a broader extent, Tottenham et al. (2011). define emotional competencies as the ability to maintain cognitive control in the context of potentially interfering emotional information. Accordingly, cognitive processes continuously modulate and regulate emotional processes (Tottenham et al., 2011). Thus, it is likely that emotion generation and emotion regulation are by no means exclusively emotional processes; rather, these involve a sophisticated and highly intertwined cognition–emotion interaction. As regards the present study, it remains unclear whether or to what extent the cognition–emotion interaction might be associated. Other researchers (Kirov et al., 2012; Lindquist and Barrett, 2012; Lindquist et al., 2012) have emphasized that emotions are generated, controlled, and regulated within different brain regions, and we speculate that brain regions, such as the prefrontal cortex and the amygdala, might be up- or downregulated during and immediately after an acute bout of exercising, depending on the intensity.

Third and again speculatively, one might assume that regular physical activity might have triggered a different degree of cognitive involvement (Tottenham et al., 2011; Phillips et al., 2003), different stages of emotion regulation (Gross, 2013; Gross et al., 2011), or differential activation of neural networks (Lindquist et al., 2012; Casey and Durston, 2006). In this view, it is conceivable that completing the questionnaires and tasks might have triggered differential activation of neural networks: Specifically, completing the Reading the Mind in the Eyes involves linguistic, and semantic emotional memory processes, which might have led to some zero-results.

Fourth, focusing again on brain networks and specifically on prefrontal network, wake-EEG-studies with individuals with major depressive disorders showed that symptom improvements were associated with both the down-regulation of the right prefrontal cortex associated with negative emotion perception and negative emotion generation, and the upregulation of the left prefrontal cortex associated with positive emotion perception and positive emotion generation (Haghighi et al., 2017; Davidson, 2003; Davidson et al., 2000; Davidson and McEwen, 2012; Davidson et al., 2002; Sutton and Davidson, 2000). However, again, the quality of the present data does not allow to further testing these hypotheses among the present sample.

The results of the active control condition demand some attention. Although participants of the ACC met 3 × /week for 30–45 min/session, no changes in participants' emotion regulation and empathy were observed. It follows that mere social interactions and social contact do not necessarily lead to changes (neither improvements, nor decreases) in an individual's cognitive-emotional and social information processing.

Despite the novelty of the results, the following limitations warrant against the overgeneralization of the results. First, exclusively female PwMS were assessed, and accordingly it remains unclear, if the pattern of results is also transferrable to male or to pediatric PwMS. Second, we fully relied on participants' self-ratings, while it would have been interesting to assess, if people living with the participants did observe changes in participants' behavior, and specifically in their degree of empathy. It follows that future studies might introduce the so-called one-for-many procedure (Holtzman and Strube, 2013) , where family members and peers are asked to evaluate behavior of a study participant. Third, latent and unassessed factors such as sleep, stress steroid concentrations, or critical life events could have biased two or more variables in the same or opposite directions. As regards sleep, this dimension was already introduced and discussed in the previous study (Sadeghi Bahmani et al., 2019); further, it appears that symptoms of insomnia and performance of facial recognition were completely unrelated. (Brand et al., 2018) It follows that sleep quality might have been a confounder, though, results from previous studies rather rule out this possibility. Fourth, a follow-up would have allowed to evaluate, if and to what extent the effects observed at the end of the present study would have remained stable or would have vanished over time.

5. Conclusions

The present study provides initial evidence that regular physical activity might favorably impact dimensions of emotion regulation and empathy among PwMS. This is clinically relevant for the quality of life of persons with MS because, also because regular physical activity is an easy and cost-effective intervention with virtually no side-effects and virtually no restrictions.

Declaration of Competing Interest

All authors declare no conflicts of interest. The entire study has been performed without external funding.

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