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Original article

The impact of COVID-19 home confinement on neuromuscular performance, functional capacity, and psychological state in Spanish people with Multiple Sclerosis

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ABSTRACT

Background: The COVID-19 pandemic caused a global confinement of more than 2 months in Spain. As a result, the general population has significantly decreased their physical activity levels. The consequences of this abrupt, sedentary lifestyle in Spanish people with Multiple Sclerosis (pwMS) were unknown. Our aim was to examine the impact of COVID-19 home confinement on neuromuscular performance, functional capacity, physical self-perception, and anxiety in pwMS.
Methods: Eighteen pwMS (8:10 men/women, age: 43.41±10.88 years, Expanded Disability Status Scale: 2.85±1.34) participated in the study. Rate of force development (RFD) and maximal voluntary isometric contraction during knee extension in both legs, Timed-Up and Go test (TUG), sit-to-stand test, 6 min walk test, 10 m walk test, Physical-Self Perception Questionnaire (PSPQ) and State-Train Anxiety Inventory (STAI) were performed just before and after home confinement.
Results: A non-significant moderate effect ($p = 0.07$; ES = -0.48) was observed in the time in the sit-to-stand test compared to pre-home confinement. There was a significant increase in the time in TUG ($p = 0.02$; ES = -0.67). The PSQP score decreased ($p = 0.01$; ES = 0.79) and STAI-state increased ($p = 0.01$; ES = -0.65) following home confinement.
Conclusion: Home confinement had an impact on functional capacity, physical self-perception and state anxiety. However, neuromuscular performance was not altered after home confinement.

1. Introduction

The COVID-19 pandemic, caused by the SARS-CoV-2 virus (Cossarizza et al., 2020) has created a global emergency since the beginning of 2020. Governments have adopted preventive actions to reduce the risk of transmission via social contact. In many countries, home confinement has been widely used and, in Spain, it has lasted more than two months. This period of confinement has affected the entire population, regardless of age or previous health status. Recently, a worldwide survey showed that mental health and multiple lifestyle behaviors (e.g., physical activity, diet, sleep quality or social participation) were altered in the general population during COVID-19 confinement. The authors showed that the greater proportion of individuals experiencing psychosocial and emotional disorders (+10% to +16.5%, respectively, compared to before COVID-19 home confinement). In addition, these psychosocial parameters were associated with unhealthy lifestyle behaviors: (i) physical (+15.2%) and social (+71.2%) inactivity, (ii) poor sleep quality (+12.8%) and (iii) unhealthy diet behaviours (+10%) (Ammar et al., 2020). In line with previous research, it has been demonstrated that home confinement leads to an increase in various psychological (Ammar et al., 2020), social and behavioral problems (González-Sanguino et al., 2020;Ammar et al., 2020). Among them, physical activity levels significantly decreased (Ammar et al., 2020). Thus, many people were forced to adopt a sedentary and inactive

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lifestyles (Ammar et al., 2020; Alomari et al., 2020; Trabelsi et al., 2021). Physical inactivity and sedentary lifestyles derived from COVID are associated with higher risk of cardiovascular disease (Pecanha et al., 2020), and poor sleep quality (Andreu-Caravaca et al., 2021). Furthermore, in general, it has been shown that a sedentary lifestyle is associated with lower levels of strength and functional capacity (González-Gross and Meléndez, 2013; Arocha Rodulfo, 2019), which suggests that confinement caused by COVID-19 may lead to a situation similar to a sedentary lifestyle. Furthermore, inactivity negatively impacts the muscular system in a short period of time, resulting in significant decreases in muscle size, alterations in the contractile properties of the muscle fiber and declines in strength per unit of cross-sectional area (Narici et al., 2020). Moreover, recent research suggests that covid-induced inactivity may lead to degeneration of the central nervous system (Narici et al., 2020). Together, the literature implies that the loss of strength is not only due to the absence of mechanical load but also to degenerative processes. Therefore, physical exercise programs, as public health strategies, are important to avoid the rapid deterioration produced by physical inactivity for the general population and especially for those populations with pathologies, such as multiple sclerosis (MS) patients.

To date, there are no conclusive studies that have determined the prevalence of COVID-19 in people with MS (pwMS). However, one recent study (3028 pwMS) showed that only 17 people (0.58%) tested positive for COVID-19 out of 3028 pwMS (Moss et al., 2020). Although it is unclear how COVID-19 affects these patients, an acute sedentary lifestyle due to home confinement (Motl et al., 2020) could worsen the symptoms of these patients and accelerate the impairments and disabilities of the disease (Dalgas and Stenager, 2012; Dalgas et al., 2019). Overall, MS patients have greater muscle weakness compared to the general population (Kent-Braun et al., 1997). Furthermore, physical inactivity, which is more prevalent in pwMS compared to healthy subjects (Casey et al., 2018), exacerbates the impairment in these variables in pwMS.

From the scientific literature and in practice, physical exercise is shown to be effective in slowing down the functional deficiencies and muscle weakness related to the disease progression in MS patients (Dalgas et al., 2009;Jørgensen et al., 2017). Increases in strength, improvements in quality of life and functional capacity, as well as reductions in symptomatic fatigue and anxiety, have been found after physical training programs in pwMS (Cruickshank et al., 2015). Training programs with different modalities, such as aerobic (Andreu-Caravaca et al., 2021), strength, or combined training, have become fundamental in treating symptoms in pwMS in the last several years (Dalgas et al., 2019; Dalgas et al., 2008).

In addition to alterations in the musculoskeletal system, pwMS suffer from psychological problems, such as anxiety, depression, and low physical and general self-perception (Boeschoten et al., 2017). Recent studies show that home confinement has a great impact on these psychological variables in other populations (Rodríguez-Rey et al., 2020), so it is presumable that the impact is similar in MS patients. To the best of our knowledge, no study has analyzed the impact of COVID-19 home confinement on muscle strength, functional capacity and psychological state in pwMS. Hence, this study aims to analyze the impact of home confinement on neuromuscular performance, functional capacity, physical self-perception and anxiety in pwMS.

2. Methods

2.1. Participants

Eighteen pwMS volunteered to participate in this study. Participants were diagnosed with Relapsing-Remitting or Primary Progressive types of Multiple Sclerosis according to the McDonald criteria (Thompson et al., 2018) by a board-certified neurologist. Participants were included if they were in the stable phase of the disease and able to walk independently for more than 10 m. PwMS were excluded if they: (1) scored <1 or >6 in the Expanded Disability Status Scale; (2) experienced a relapse within the prior 12 months; (3) were taking corticosteroid treatment within the preceding 2 months; (4) were involved in a resistance or aerobic training program in the 4 months prior to home confinement; and (5) were involved in a home-training program during home confinement. All participants read and signed an informed consent before starting the study.

2.2. Study design

All testing sessions were performed in the UCAM Sports Center (Murcia, Spain). All evaluations occurred at the same time of day to minimize the differing changes in the circadian rhythm responses. In the first visit, subjects were familiarized with all testing procedures. Additionally, the height was measured using a tallimeter (Seca 709, Hamburg, Germany), and weight, lean mass and fat mass were assessed via electronic bioimpedance (Tanita Corp., Tokyo, Japan). After 48 h, subjects returned for the second visit to perform the neuromuscular assessment. Visit 3 occurred 48 h following visit 2 where participants performed the functional capacity test battery and completed the questionnaires. Pre-confinement measurements were taken during the week of March 1–5, 2020. Post-confinement measurements were conducted on June 8–12, 2020. The State of Alarm was decreed in Spain on March 14, 2020, and all citizens were confined to their homes, except for strictly necessary reasons (e.g., medical emergency, buy food, etc.). All gyms, sports centers and physiotherapy clinics were closed. As of May 9th, Spanish citizens were allowed to go out for a walk or do sports for one hour during a pre-determined hour of the day. From June 1st and on, citizens were allowed to be outside without restrictions, although gyms and sports centers were still closed. Participants performed the testing measurements immediately before and after home confinement. This study was approved by the Science Ethics Committee of the Catholic University of Murcia in accordance with the Declaration of Helsinki. It should be noted that the baseline measurements were completed just before the National State of Alarm, forcing the whole population to home confinement. These baseline measures were originally meant for an experimental intervention study, which was suspended due to the COVID-19 pandemic. When the home confinement restriction was lifted, we felt it important to follow-up on these study participants.

2.3. Testing procedures

For each visit, participants performed a standardized warm-up of 5 min on a cycle ergometer at 50 W and a dynamic stretching routine. Each assessment was conducted by the same researcher. The primary outcome variables were maximal voluntary isometric contraction (MVIC) and rate of force development (RFD), which represent neuromuscular performance. The secondary outcome variables consisted of functional capacity tests (Timed Up and Go test (TUG), Sit-to-stand test, 10 m walk test and 6 min walk test), the Physical Self-Perception Questionnaire (PSPQ) and the State-Trait Anxiety Inventory (STAI).

2.3.1. Neuromuscular testing: maximal voluntary isometric contraction and rate of force development

Participants were seated on the isokinetic dynamometer chair (Biodex Medical System, NY) with both legs flexed at 90° and the testing leg's ankle strapped directly to a customized apparatus with a load cell (Model SML500, Interface Scottsdale, AZ, USA). To warm-up, each subject performed 3 progressive MVICs with 3 min of rest between attempts. To assess RFD in each leg, verbal encouragement was given to the participants to apply "as much force as possible, as fast as possible" throughout the 2 consecutive maximal contractions. RFD was analyzed using the following time intervals 0–50 ms (RFD_{early}) and 0–200 (RFD_{late}). Subsequently, participants performed 2 MVICs, each lasting for 5 s with 3 min of rest between contractions, with verbal encouragement. Maximal torque (MVIC) and time to peak voluntary torque (time-to-MVIC) were evaluated. The right leg was always evaluated first, and the trial with the highest value was used for both RFD and MVIC.

2.3.2. Sit-to-stand test

The sit-to-stand test evaluated the time a participant required to stand quickly as possible from the sitting position. Participants began the test seated upright in an adjustable chair (based on the lower limb length) with the knees flexed at 90° and the arms crossed over the chest. The end time was determined via video recording analysis, when the participant's trunk and knees were fully extended. Participants repeated the test 2 time using the best trial for analysis.

2.3.3. Timed up and go test

Participants were asked to stand up from the seated position, walk three meters in the forward direction, turn around, walk back to the start, and sit down again as quickly as possible. The fastest time of two trials was determined via video recording and used for analysis.

2.3.4. 10-meters walk test

Participants were instructed to walk as quickly as possible for 10 m (marked by taped lines) without running. The test was repeated after 2 min of rest. Verbal encouragement was given throughout the test. Two photocells (Witty, Microgate, Italy) were placed at 6 and 10 m to record walking time. The lowest walking time was used for the analysis.

2.3.5. 6-min walk test

Participants walked for six minutes at their preferred walking speed. The test was carried out on a rectangular track (40 x 20 m) defining the corners with cones. Subjects were allowed to rest if needed, but the time did not stop during their rest period. The total distance (m) covered after six minutes of walking was measured. All patients were accompanied by the investigator during the test but were not allowed to make conversation.

2.3.6. Physical-self perception questionnaire

The PSQP, validated and published by Grandmontagne et al. (2004), consists of six subscales that assess self-perception in sports competence, physical condition, attractive body, physical strength, general physical self-perception, and general self-perception. The answers are structured on a 5-point Likert scale, where each subscale score may range from 6 to 36 points. The Cronbach's coefficient alpha of each subscale was as follows: sports competence (0.783), physical condition (0.833), attractive body (0.859), physical strength (0.839), general physical self-perception (0.871) and general self-perception (0.764).

2.3.7. State-trait anxiety inventory

This questionnaire evaluates and discriminates the temporary psychological state to a given situation (state anxiety; 20 items) and the more stable character trait of attitudes and temperaments (trait anxiety; 20 items) (Spielberger and Reheiser, 2004). It is especially useful for the diagnosis of anxiety disorders in non-psychiatric patients. The State-Trait Anxiety Inventory (STAI) uses a 4-point Likert scale, and the score may range from 10 to 40 points for each subscale. The Cronbach's coefficient alpha was 0.92 (IC95%: 0.91–0.93) for the state anxiety subscale and 0.91 (IC95%: 0.90–0.92) for trait anxiety subscale (Guillén-Riquelme and Buela-Casal, 2014).

2.4. Statistical analyses

SPSS for Windows statistical package (version 20.0; SPSS, Inc., Chicago, IL, USA) was used for data analysis. Descriptive statistics (mean and standard deviation (SD)) were determined. The assumption of normality and homoscedasticity was confirmed with the Shapiro-Wilks test before using parametric tests. The Student's *t*-test for paired samples was used to detect significant changes between pre and post home confinement. A level of $p \leq 0.05$ was established for statistical significance. The effect size (ES) was calculated using Cohen's guidelines [ES = (Mean Post – Mean Pre)/ SD difference] (Cohen, 2013).

3. Results

Seventeen pwMS (7 men, 10 women; age: 43.5 ± 11.2; EDSS: 2.9 ± 1.4; weight: 70.6 ± 12.3 kg; height: 167.7 ± 7.2 cm; lean mass: 51.7 ± 9.6 kg; fat mass: 27.5 ± 9.8%; BMI: 25.0 ± 3.4 kg/m^2) completed the study, where one participant dropped out due to schedule conflicts with the testing sessions. Fifteen people presented relapsing-remitting multiple sclerosis, and 2 secondary-progressive multiple.

3.1. Neuromuscular performance

There were no pre-post changes found in MVIC, $MVIC_{time\text{-}to\text{-}peak}$, RFD_{early} and RFD_{peak} in both legs (Table 1).

3.2. Functional capacity

Regarding sit-to-stand, a non-significant moderate effect size (ES = −0.48) was observed in the time required to perform the test post-confinement, tending towards an increase in time. In addition, a significant increase was shown in the time required to perform TUG (ES = −0.67, $p = 0.02$) (Table 2).

3.3. Physical-self perception questionnaire and state-trait anxiety inventory

Significant decreases were found in all subscales of the PSPQ (sports competence: *ES* = 0.54, $p = 0.04$; physical condition: ES = 0.64, $p = 0.02$; attractive body: ES = 0.59, $p = 0.02$; physical strength: ES = 0.51, $p = 0.05$; general physical self-perception: ES = 0.79, $p = 0.01$), except for general self-perception. Regarding STAI, significant increases were shown in Anxiety State (ES = −0.65, $p = 0.01$) but not in Anxiety Trait (Table 3).

4. Discussion

After 2 months of home confinement, pwMS did not show a change in any of the neuromuscular performance variables. However, there was a worsening in functional capacity. In addition, a lower physical self-perception and a greater anxiety state were found after home confinement.

4.1. Neuromuscular performance

No changes were observed in MVIC and RFD variables. Previous studies have shown that changes in RFD are generally associated with changes in MVIC (Andersen et al., 2010). In contrast, our study did not find a significant decrease in RFD and MVIC. Several studies have determined that changes in the magnitude of RFD can be caused by a change in the structural components of the muscle (cross-sectional area, modification of fiber type…) or due to alterations in the neural component (recruitment of motor units and frequency of discharge) (Carroll et al., 2011). Furthermore, the early rate of force development ($RFD_{early)}$ during the first 50 ms of contraction is largely affected by the neural component and intrinsic contractile properties of the muscle (Andersen and Aagaard, 2006), while the RFD 0–200 ms (RFD_{late}) is more influenced by the structural component (Andersen et al., 2010). Mulder et al. (2006) observed than after a period of inactivity due to the bed rest, structural component variables are generally affected first, while the neural component variables tend to change later. However, Mulder et al. (2006) findings could be contributed by their frequent testing of neuromuscular function during the intervention period, which

Table 1
Pre-post effect comparison in neuromuscular outcomes.

Neuromuscular outcomes	Pre (Mean±SD)	Post (Mean±SD)	Δ± ΔSD	t	p	Effect Size	95% CI for Cohen's d Lower	Upper
Right leg								
MVIC (N· m)	464.60±201.72	476.29±179.05	0.06±0.19	−0.82	0.42	−0.21	−0.70	0.29
$MVIC_{time\text{-}to\text{-}peak}$ (s)	2.34±0.92	2.13±2.24	−0.04±0.25	1.29	0.21	0.32	−0.19	0.82
RFD_{early} (N· m s^{-1})	100.78±39.57	100.29±40.20	−0.01±0.15	0.20	0.84	0.05	−0.44	0.54
RFD_{late} (N· m· s^{-1})	231.29±99.59	241.00±97.11	0.07±0.20	−1.08	0.29	−0.27	−0.76	0.23
Left leg								
MVIC (N· m)	387.69±224.71	399.02±218.81	0.05±0.07	−1.36	0.19	−0.66	−1.19	−0.11
$MVIC_{time\text{-}to\text{-}peak}$ (s)	1.84±0.69	1.96±0.71	0.14±0.38	−0.86	0.40	−0.22	−0.71	0.28
RFD_{early} (N· m· s^{-1})	92.40±39.65	94.41±39.12	0.04±0.17	−0.58	0.57	−0.15	−0.63	0.35
RFD_{late} (N· m· s^{-1})	225.10±110.16	226.07±115.97	−0.01±0.13	−0.14	0.88	−0.04	−0.53	0.45

CI: Confidence Interval; MVIC: Maximal voluntary isometric contraction; RFD: Rate of force development.
*$p \leq 0.05$ pre-post differences.

Table 2
Pre-post effect comparison in functional capacity.

Functional capacity	Pre (Mean±SD)	Post (Mean±SD)	Δ± ΔSD	t	p	Effect Size	95% CI for Cohen's d Lower	Upper
Sit-to-stand (s)	1.03±0.67	1.07±0.64	0.06±0.09	−1.91	0.07	−0.48	−0.99	0.05
TUG (s)	11.90±9.75	12.20±9.95	0.02±0.03	−2.69	0.01*	−0.67	−1.21	−0.12
10-MWT (s)	6.62±7.04	6.21±6.46	−0.01±0.12	1.05	0.31	0.26	−0.24	0.76
6-MWT (min)	464.00±266.00	477.00±290.00	0.01±0.13	−0.66	0.51	−0.17	−0.66	0.33

CI: Confidence Interval; TUG: Timed Up and Go test; 6-MWT: 6-min walk test; 10-MWT: 10-meters walk test.
*$p \leq 0.05$ differences pre-post.

Table 3
Pre-post effect comparison in Physical Self-Perception and State-Trait Anxiety Inventory.

Psychological Outcomes	Pre (Mean±SD)	Post (Mean±SD)	Δ± ΔSD	t	p	Effect Size	95% CI for Cohen's d Lower	Upper
Physical Self-Perception								
Sports competence	17.90±5.59	16.00±3.94	−0.08±0.14	2.24	0.04*	0.54	0.02	1.05
Physical condition	17.40±5.53	15.30±3.74	−0.08±0.22	2.63	0.02*	0.64	0.11	1.15
Attractive body	19.40±5.30	17.50±4.33	−0.08±0.14	2.44	0.02*	0.59	0.07	1.10
Physical strength	17.20±3.96	16.30±3.35	−0.04±0.10	2.11	0.05*	0.51	−0.01	1.01
General physical-self perception	17.80±4.28	15.10±2.59	−0.13±0.15	3.25	0.01*	0.79	0.23	1.32
General self perception	17.20±3.09	16.40±2.15	−0.03±0.16	1.09	0.30	0.26	−0.22	0.74
STAI								
STAI-State	17.40±12.77	22.10±11.8	0.55±0.83	−2.69	0.01*	−0.65	−1.17	−0.12
STAI-Trait	20.60±11.14	21.80±9.80	0.16±0.28	−1,35	0.19	−0.33	−0.81	0.17

CI: Confidence Interval; STAI: State-Trait Anxiety Inventory.
*$p \leq 0.05$ differences pre-post.

would theoretically stimulate the nervous system (and intrinsic contractile properties) but less likely the structural component. In this context, other research have indicated that the neural component has a great capacity to adapt to both training and disuse (Narici and De Boer, 2011; Rejc et al., 2018).Medina-Perez et al. (2014) examined the effect of 12 weeks of resistance training followed by 12 weeks of detraining on MVIC and muscle power. They showed that pwMS improved MVIC and muscle power after resistance training. However, after detraining, the muscle power achieved remained higher than baseline while MVIC decreased and returned to baseline values. Therefore, the strength increases observed in this study are most likely attributed to the neural component (muscle power), which appears to have lasting effects after training than the strength manifestations that are related to the structural component (MVIC).

In recent years, the relationship between RFD and different functional tests has been studied, as well as with the risk of falls in at-risk populations, such as the elderly or pwMS (Kjølhede et al., 2015). These studies have shown that pwMS who have higher levels in RFD_{late} have better performance in different functional tests, such as the time needed to get up from a chair or walk a certain distance (Kjølhede et al., 2015). Therefore, monitoring the state of RFD in pwMS is essential and can be an important variable in providing valuable information regarding the patient's functional status.

4.2. Functional capacity

The performance in TUG and sit-to-stand test decreased after home confinement in pwMS. Sedentary behaviour and time spent sitting have been associated with loss of functional capacity in both healthy (Narici et al., 2020) and pathological populations (Dürr et al., 2014), and is a common behaviour among pwMS (Casey et al., 2018), which has been correlated with poorer performance in functional capacity (Rooney et al., 2019). For pwMS, certain tasks of daily life are a real challenge, so improving the ability to perform them without reaching high fatigue is a challenge for rehabilitation and exercise professionals. On the other hand, numerous studies have analyzed the improvements in different functional tests produced by physical exercise, such as getting up from a chair or walking performance in pwMS (Dalgas et al., 2009). According to previous studies, improving functional capacity in pwMS could lead to an increase in the quality of life (Dalgas et al., 2010) and a decrease in symptomatic fatigue, which underlines the importance of measuring and improving these variables (Dalgas et al., 2019; Jørgensen et al., 2017).

According toRamari et al. (2020), the task performance, such as sit-to-stand, is affected by knee extensor MVIC. In addition, a systematic review with meta-analysis byRamari et al. (2020) stated that lower-limb functional test correlates with muscle strength in the weaker leg more so than with the stronger leg in pwMS. Our results show decreases in sit-to-stand and TUG performance. However, no decreases have been found in 6-MWT and 10-MWT. Similar to these findings, other authors have found very low correlations between muscle strength in both legs and short-long walking tests (Almuklass et al., 2018). Therefore, the relationship between these variables is not entirely clear.

4.3. Physical self-perception and anxiety

Anxiety-state increased and physical self-perception decreased after confinement in pwMS. Psychological problems, such as depression, loneliness and anxiety, have risen in the general population during home confinement and COVID-19 pandemic (Bartoszek et al., 2020). The restrictions on social contacts, fear of contagion, economic crisis, the threat of unemployment, and the fear of losing a family member are some of the causes for these psychological problems (Bartoszek et al., 2020). It has been demonstrated that physical activity plays an important role in modulating one's mood and psychological state. Therefore, the quantity of physical activity has been correlated with self-concept, anxiety (Chen et al., 2019) and depression in the general population, as well as in people with long-term physical disabilities (Battalio et al., 2020). The amygdala, a cerebral structure responsible for processing events produced by fear, can be activated by stimuli that are non-threatening and produce anxiety. Numerous studies have shown that physical exercise can regulate the activity of the amygdala (Chen et al., 2019). A meta-analysis by Wegner et al. (2014) reported that physical activity leads to physiological changes in the levels of cortisol (stress hormone) and causes adaptations in limbic structures associated with depression as well as increased regulation of neurotrophic factors. Therefore, the forced sedentary lifestyle due to home confinement may explain heightened anxiety and diminished physical self-perception found in our study.

To the best of our knowledge, this is the first study that investigated the direct consequences of home confinement because of the COVID-19 pandemic on neuromuscular performance, functional capacity and psychological state in pwMS. However, the main limitations of this study are the reduced sample size and the heterogeneity of the sample (i.e., gender, type of MS, etc.), necessitating precaution when interpreting the findings.

4.4. Limitations

One of the main limitations of the study is the lack of accelerometry data regarding the level of physical activity prior to and during confinement. These data would have given us more information and provided better interpretation of the results. However, due to the peculiarities of the national State of Alarm, it was impossible to include these measurements in the study design.

4.5. Practical recommendation

As this and other studies have reported, home confinement has a great impact on people with MS, and it would be essential to carry out interventions that promote an Active and Healthy Confinement Lifestyle (AHCL). Following the recommendations proposed by Bentlage et al. (2020), supervised and individualized virtual training programs, including the use of exergames can be a valid tool to reduce the negative impact of home confinement. Additionally, the inclusion of relaxation techniques to reduce stress has been proposed by these authors during this period. Similarly, Chtourou et al. (2020) highlighted the importance to accumulate at least 150 min of weekly exercise of moderate intensity and 75 min of vigorous intensity, divided into 5–7 sessions per week. For this, home-based exercise, exergaming, dancing to music and participation in yoga are viable options to fulfill the aforementioned recommendation with the help of phone applications or wearable sensors to monitor the activity level. Finally, it is recommended that exercise professionals rely on digital technological solutions to ensure AHCL, especially in vulnerable populations, such as MS. These types of applications allow for closer monitoring and supervision of their clients (Ammar et al., 2021).

5. Conclusions

Home confinement caused by COVID-19 has resulted in significant decreases in functional capacity, and physical self-perception, as well as an increase in anxiety-state in pwMS. However, neuromuscular performance was not affected. These findings demonstrate the consequences of forced physical inactivity in this population, as well as highlight the need to implement at-home training programs to aid the rehabilitation process and psychological state for pwMS.

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CRediT authorship contribution statement

Luis Andreu-Caravaca: Conceptualization, Project administration, Formal analysis, Writing – original draft, Writing – review & editing. **Domingo J Ramos-Campo:** Conceptualization, Project administration, Writing – review & editing, Formal analysis. **Linda H Chung:** Investigation, Writing – review & editing. **Pedro Manonelles:** Project administration, Writing – review & editing. **Oriol Abellán-Aynés:** Project administration, Writing – review & editing. **Jacobo Á Rubio-Arias:** Conceptualization, Project administration, Formal analysis, Writing – review & editing.

Declaration of Competing Interest

None.

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