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ORIGINAL ARTICLE

# Beneficial effects of a supervised and individualized training circuit on physical capacities and quality of life of patients suffering from multiple sclerosis

## *Effets bénéfiques d'un circuit d'entraînement supervisé et individualisé sur les capacités physiques et la qualité de vie des patients souffrant de sclérose en plaques*

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**KEYWORDS**
Multiple sclerosis;
Physical training;
Quality of life;
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Muscle strength;
Task oriented circuit training

**Summary**
*Objective.* — Rehabilitation strategies using adapted physical activities in multiple sclerosis (MS) have been poorly studied. The purpose of our study is to evaluate the impact of an 18-week program of adapted-training sessions (i.e., task-oriented circuit training, TOCT) on physical capacities and quality of life of patients suffering from MS.
*Methods.* — The program was composed of 3 sessions per week, one supervised by two physiotherapists which consisted of TOCT of 75 min; and two other sessions which consisted of an independent walking exercise of 30 min. Primary outcomes were walking abilities and quality of life. Secondary outcomes were handgrip strength, finger dexterity, lower limb strength endurance, fatigue, depression/anxiety and cardiorespiratory endurance.

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*Results.* — Fourteen patients were included in analyses. TOCT significantly enhanced patients' ability to perform the walking tests (improvement of +12.8% for the Timed 25-foot walk test [*P* = 0.006], +9.56% for the 100-meter walk test [*P* = 0.001], +8.91% for the 500-meter walk test [*P* = 0.03] and +20.35% for the Six Spot Step Test [*P* = 0.03]) and improved the mental component scale of the SF-36 questionnaire (+14.3% [*P* = 0.03]). Some secondary outcomes also improved following TOCT: dexterity of the non-dominant hand (+5.28%, *P* = 0.024), the 30-second chair stand test (+13.2%, *P* = 0.002) as well as the cardiorespiratory endurance (+9.21%, *P* = 0.02). No difference of handgrip strength, fatigue and depression/anxiety was notified.
*Conclusion.* — Despite not using a controlled design, this interventional pilot study suggests the feasibility and potential beneficial effects of an adapted training program in walking abilities, mental health quality of life, dexterity of the non-dominant hand and physical performance of multiple sclerosis patients. The beneficial effects of the intervention deserved to be confirmed in well-conducted randomized controlled trials.


**MOTS CLÉS**
Sclérose en plaques ;
Entraînement physique ;
Qualité de vie

**Résumé**
*Contexte.* — Les stratégies de réadaptation utilisant des activités physiques adaptées dans la sclérose en plaques (SEP) ont été peu étudiées. L'objectif de notre étude est d'évaluer l'impact d'un programme de 18 semaines de séances d'entraînement adaptées (TOCT) sur les capacités physiques et la qualité de vie des patients souffrant de sclérose en plaques (SEP).
*Méthodes.* — Le programme était composé de 3 séances par semaine, l'une sous forme de TOCT de 75 min, supervisée par deux physiothérapeutes; et deux autres séances composées de 30 min de marche non supervisée. Les critères d'évaluation principaux étaient les capacités de marche et la qualité de vie. Les critères d'évaluation secondaires étaient la force de préhension, la dextérité des doigts, l'endurance de la force des membres inférieurs, la fatigue, la dépression/anxiété et l'endurance cardiorespiratoire.
*Résultats.* — Quatorze patients ont été inclus dans l'étude. L'entrainement proposé sous forme de TOCT semble améliorer de manière significative la capacité des patients à effectuer les tests de marche (amélioration de +12,8 % pour le 25-foot walk test [*P* = 0,006], +9,56 % pour le test de marche de 100 mètres [*p* = 0,001], +8,91 % pour le test de marche de 500 mètres [*p* = 0,03] et +20,35 % pour le *Six Spot Step Test* [*p* = 0,03]) et améliorer également la composante mentale du questionnaire SF-36 (+14,3 % [*p* = 0,03]). Certains critères d'évaluation secondaires se sont également améliorés suite au programme de revalidation: la dextérité de la main non dominante (+5,28 %, *p* = 0,024), le test du lever de chaise ((+13,2 %, *p* = 0,002) ainsi que l'endurance cardiorespiratoire (+9,21 %, *p* = 0,02). Aucune différence au niveau de la force de préhension, de la fatigue et de la dépression/anxiété n'a toutefois été notifiée.
*Conclusion.* — Bien que n'utilisant pas un design d'étude randomisée contrôlée, cette étude pilote interventionnelle suggère la faisabilité et les effets bénéfiques potentiels d'un programme d'entraînement adapté sur les capacités de marche, la qualité de vie en santé mentale, la dextérité de la main non dominante et les performances physiques des patients atteints de sclérose en plaques. Les effets bénéfiques de l'intervention méritent d'être confirmés par des essais contrôlés randomisés de bonne qualité.


## 1. Introduction

Multiple sclerosis (MS) is a chronic, degenerative and disabling autoimmune disease of the central nervous system (CNS) characterized by inflammation, demyelination and neurodegenerative disorder of the central nervous system [1]. The expression of symptoms can be very heterogeneous among patients, depending on the degree and location of the axonal injuries in the CNS [2,3]. The most common reported symptoms in MS are fatigue and muscle weakness, closely related with the ability to walk, which is one of the most important factors impacting patients' autonomy in their daily live activities and their quality of life [4].

Because of their symptoms, people with MS are less physically active than healthy adults of the same age, with an aerobic capacity reduced by up to 30% [5,6]. It has been shown that the cessation of physical activity may lead to physical deconditioning that can, ultimately lead to an aggravation of the handicap [7]. Physical activity is therefore recommended as an essential part of the therapeutic arsenal in the treatment of MS [8]. Over the past decade, the benefits of physical activity on fatigue, depression, muscle strength, mobility and quality of life have been widely demonstrated in people with MS [9,10]. Most of these studies used a standardized protocol of rehabilitation with progressive resistance training and/or endurance training [11,12]. However, given the heterogeneity of the clinical expression of the disease among patients, a standardized protocol may not be adapted for many patients with MS. In this context, exercises proposed to these patients should be personalized to focus on the patient's individual deficits and should focus as much as possible on the patient's specific goals [13].

Moreover, researchers have also focused on the impact of socialization on people with MS [14]. Indeed, the increased possibility of interpersonal relationships with exercise seems to lead to a higher level of motivation during training [15]. Group sessions may allow patients to meet, discuss, encourage and support each other, which could have a significant impact on their well-being and quality of life [16—18]. Individualized task-oriented circuit training, know under the abbreviation of TOCT in literature, could be an interesting option for patients suffering from MS because it consists of personalized exercises based on the patient's individual abilities, wishes and goals. TOCT is usually performed in groups, which can potentially increase participation and adherence [19].

Since very few studies tested TOCT as an intervention in MS with the purpose to improve walking abilities and quality of life, we developed an open-label interventional pilot study that evaluates the impact of three weekly physical training sessions, including one supervised and collective session called the individualized task-oriented circuit training (TOCT), as well as two walking sessions, over an 18-week period, on the physical capacities and quality of life of patients suffering from MS.

## 2. Methods

### 2.1. Study design

We developed an open-label prospective longitudinal interventional study, not randomized and not controlled. We measured pre-post differences of primary and secondary outcomes in MS patients that underwent an 18-week physical training program. The study was approved by the local Ethical Committee of the CHA VIVALIA of Libramont, Belgium, by the Ehical Committee of ''Cliniques Sud-Luxembourg CSL'', Luxemburg, as well as the Ethical Committee of ''Centre Hospitalier Universitaire CHU Godinne-Dinant'', Belgium.

### 2.2. Population

Patients were recruited from a database available in the Neurology Department of CHA Vivalia Libramont, Belgium as well as from the ''Comité Luxembourgeois de la Ligue de la Sclérose en Plaques''. All forms of MS were included: relapsing remitting forms as well as primary and secondary progressive forms. To be included, patients had to score less than 6 on the Kurtzke Expended Disability Status Scale (EDSS) [20], which translates a minor to moderate disability status. Moreover, pregnant women and patients that presented relapses (i.e. period characterised by a worsening of symptoms) during the previous 3 months were excluded.

### 2.3. Training program

The training program was composed of 3 sessions per week during18 weeks.

Collective supervised training session (once a week): each week, patients were invited to participate to a collective supervised training session of 60 min. This training session was presented under the form of a TOCT and was organized in a Sport Center. Along the circuit, 12 workshops were proposed with different levels of intensity. The workshops were continuously adapted to patients' capacities. Each workshop required a 2-minute training work with a 30-second rest between 2 workshops. Each session was supervised by two physiotherapists who ensure to switch the different exercises proposed to limit a potential recall bias or lassitude. The physiotherapists were present to help participants with the exercises and ensure a correct posture for each exercise in order to maximize the beneficial effect of the training and limit the risk of falls or injuries.

The training session consisted of five different parts (see Table 1):

- a warm-up;
- a first session of exercise where patients were invited to exercise on the 12 different workshops;
- a small break;
- a second session where patients could choose to exercise again on 4 different workshops, (5) a stretching session.

For each of the 4 workshops, different levels of exercise were proposed and adapted to the physical abilities of each patient.

During the individual non-supervised training sessions (twice a week), patients were invited to participate in two walking sessions of 30 min each week in addition to the collective supervised session. Patients were invited to record all training sessions in a diary to ensure a good adherence.

### 2.4. Outcomes

Different outcomes were measured at baseline (inclusion of participants, T0) and at the end of the 18-week training program (T1). Standardized procedures have been ensured for both T0 and T1 data collection.

#### 2.4.1. Primary outcomes

Walking abilities were measured through 4 different tests:

- Timed 25-foot walk test (T25-FW) [21], for which participant were invited to walk a 25-foot distance at their maximal gait speed. The best recorded time of two trials is reported as result of this walk test;
- 100-meter walking test [22,23], for which participants are invited to walk 100 meters at their maximal gait speed. This test reflects performances on a short distance;
- 500-meter walking test [23], for which participants are invited to walk 500 meters. This test reflects functional capacities at a sub-maximal level;
- Six Spot Step Test (SSST) [24], for which participants are invited to place different elements on the ground, outside of a specific area using, on alternance, the

**Table 1** Description of the TOCT and the 12 workshops.

| Phase | | Length (minutes) | Exercises | | |
|---|---|---|---|---|---|
| Warm-up | | 5 | Walk freely in the room, taking care to avoid the equipment set up | | |
| TOCT (12 workshops) | 1 full session of 12 workshops | 30 | Workshop | Targeted muscles | Exercises |
| | | | Walking<br>(2 workshops) | Global musculature with lower muscles and spine stabilizer +++ | Speed course<br>Technical course (front, back, side, obstacles, juggling, shooting...) |
| | | | Muscle strength lower limbs<br>(4 workshops) | Quadriceps, hamstrings, gluteus maximus, gluteus Medius, gastrocnemius | Squats<br>Forward and backward lunges<br>Step up and down<br>Tiptoeing |
| | | | Muscle strength upper limbs<br>(2 workshops) | | Push-pull standing at the espalier<br>Dips<br>Bicep's curl<br>Dumbbell combination |
| | Break | 3 | | | |
| | Free choice of 4 workshops | 10 | Sleeving/stabilization<br>(3 workshops) | Abdominals, lumbar spine, back | Front board<br>Side plank<br>The bridge<br>The quadruped |
| | | | Balance<br>(1 workshops) | Postural muscles | Walking on a beam<br>Walking on unstable foam<br>Throw a ball and catch it on 1 foot |
| Stretching | | 10 | All major muscle groups | | |
| Total length: 58 | | | | | |

external/internal edge of the foot. This test reflects the coordination and balance of lower limbs. It is also a double-task test using cognitive and visual system.

Quality of life was measured using the Short-Form 36 questionnaire (SF-36) [25], which is a multi-item generic health survey using 36 questions to measure functional health and well-being based on the patient's perspective. This questionnaire generates quality of life data for two dimensions: the mental physical component scale and the physical component scale.

#### 2.4.2. Secondary outcomes

Different secondary outcomes were also collected. The level of fatigue was measured using the Fatigue Impact Scale (FIS) [26]; the level of depression/anxiety was measured using the Hospital Anxiety and Depression Scale (HADS) [27], the handgrip strength was measured with a handheld Jamar dynamometer (6 measures were collected, 3 for dominant hand and 3 for non-dominant hand with the mean values of the three measurements reported for each hand); the motricity and dexterity of lower limb was measured using the Nine Hole Peg test (NHTP) [28]; the level of endurance for lower limbs measured using the 30-second chair stand test and, finally, the cardiorespiratory endurance measured by cycloergometry at a maximal heart frequency of 65%. For this last test, participants were asked to respect a cycling frequency of 60 cycle/minute. The baseline power was 25 watts with an increased power of 25 watts every 2 min. The test was terminated when the heart frequency of participants reached 65% of the maximal heart frequency.

### 2.5. Analyses

Analyses were performed only on patients who did not present any relapse during the 18-week training program

**Table 2** Characteristics of the included population.

| | MS participants ($n = 14$) |
|---|---|
| Age (years) (median, P25-P75) | 48.3 (40.2—56.6) |
| Sex | |
| Women (*n*, %) | 11 (78.6) |
| BMI (kg/m$^2$) (median, P25-P75) | 25.1 (20.7—29.6) |
| Physical activity/week | |
| < 1 x/week (*n*, %) | 3 (21.4) |
| 1-2 x/week (*n*, %) | 7 (50) |
| ≥ 3 x/week (*n*, %) | 4 (28.6) |
| Smokers (*n*, %) | 4 (28.6) |
| Working status | |
| Full-time work (*n*, %) | 2 (14.3) |
| Partial time (*n*, %) | 5 (35.7) |
| Invalidity (*n*, %) | 5 (35.7) |
| Retired (*n*, %) | 2 (14.3) |
| Type of MS | |
| Relapsing-remitting form (*n*, %) | 11 (78.6) |
| Primary progressive (*n*, %) | 2 (14.3) |
| Secondary progressive (*n*, %) | 1 (7.1) |
| Length with disease (years) (median, P25-P75) | |
| Relapsing-remitting form | 9.64 (1.37—17.9) |
| Primary/secondary progressive | 9.33 (1.82—16.8) |
| Treatment for MS | |
| First line (*n*, %) | 7 (50) |
| Second line (*n*, %) | 3 (21.4) |
| Asymptomatic (*n*, %) | 4 (28.6) |
| Walking aid | |
| Yes (*n*, %) | 2 (14.3) |

MS: Multiple Sclerosis

and patients who presented a training adherence superior to 80%. Others were excluded from the analyses.

All analyses were performed using Xlstat. Normality of variables was tested using the Shapiro-Wilk test. Quantitative variables were expressed as median and interquartile range (p25-p75) when non normally distributed or as mean ± SD when normally distributed. Qualitative variables were expressed as frequencies absolute (*n*) and relative (%). To test the impact of the training on primary and secondary outcomes between baseline (T0) and the end of the 18-week training program (T1), the non-parametric Wilcoxon test was used. The significant level of 0.05 was use throughout all our analyses.

## 3. Results

Out of 63 patients who met our inclusion criteria, 17 agreed to participate to this interventional study. However, only 14 participants were included in the final analyses. Indeed, 3 patients were excluded because of an insufficient adherence to the program or relapses. The characteristics of the 14 patients included in the analyses are presented in Table 2. The median age was 48 years, and the majority of participants were women ($n = 11$, 78.6%). Patients have a median BMI of 25 kg/m$^2$ and 28.6% were smokers. Majority of them had a relapsing remitting form of MS (78.6%), others presented a primary progressive MS (14.3%) or a secondary progressive MS (7.1%). A walking aid was necessary for 2 of the participants (14.3%).

### 3.1. Effect of training program on gait and quality of life

Following the 18-week TOCT program, patients significantly enhanced their walking abilities. All of the four walking tests improved significantly, with a percentage of improvement raising from +9.56% for the 100-meter walk test to +20.35% for the SSST test (all *P*-values < 0.05) (Table 3). Patients' quality of life only improved for the mental component scale (+14.3%, $P = 0.03$).

### 3.2. Effect of training program on secondary outcomes

The proposed program was beneficial for some of the investigated parameters such as motricity and dexterity of fingers of the non-dominant hand (+5.28% of improvement after the 18-week training program, $P = 0.02$), the physical resistance (+13.2% of improvement of the 30-seconds chair stand test, $P = 0.002$), and finally, the cardiorespiratory resistance (+9.21% of improvement in the cycle ergometer test, $P = 0.02$). Other investigated parameter did show any difference at a statistical level (Table 4).

## 4. Discussion

This 18-week interventional study in patients with MS aimed to evaluate the efficacy of an adapted and individualized program (TOCT) combined with individual non-supervised sessions on patients walking abilities and quality of life. This pilot study suggested that this specific training, combining muscle strengthening and aerobic training, may improve walking abilities, quality of life in its mental component, motricity and dexterity of the non-dominant hand, physical resistance of lower limbs and, finally, cardiorespiratory resistance. However, the proposed training did not improve patients' quality of life in its physical component, anxiety, depression, and grip strength.

Despite that it has long been recommended that people suffering from MS should avoid physical exercise because it may worsen symptoms or fatigue, the beneficial effect of physical activities for this population is now generally accepted. However, because of the broad range of possible exercises, it is still difficult to develop unified recommendations for pathologies such as MS. To overcome the issue of symptoms' heterogeneity and different grades in the disease severity, we hypothesized that an adapted and supervised physical activity program guided by practitioners familiar with the pathology may be beneficial for this population. In pathologies such as MS, because of the physical limitations and the related fatigue, it seems indeed relevant to propose a personalized and safe approach to each patient with the possibility of permanent adaptations of the intensity or type of exercise. Moreover, TOCT also involves social and playful aspects, which are advantages of group therapies [29]. The proposed physical activity under the form of a supervised and adapted TOCT have been shown to be highly feasible

**Table 3** Effect of training program on primary outcomes (walking tests and quality of life).

| Test | Pre-test (T0) mean ± SD | Post-test (T0) mean ± SD | Inter-assay CV (%) | Mean difference ± SD | Percentage of improvement | *P*-value* |
|---|---|---|---|---|---|---|
| T25-FW (seconds) | 5.54 ± 2.6 | 4.83 ± 1.93 | 10.40% | -0.71 ± 2.29 | +12.8% | 0.006 |
| 100-meter walk (seconds) | 70.4 ± 31.5 | 63.7 ± 25.3 | 6.26% | -6.7 ± 28.6 | +9.56% | 0.001 |
| 500-meter walk (seconds) | 377.6 ± 200.5 | 343.9 ± 148.8 | 5.99% | - 33.7 ± 176.5 | +8.91% | 0.03 |
| SSST (seconds) | 12.6 ± 10.6 | 10 ± 6.41 | 10.80% | -2.6 ± 8.76 | +20.35% | 0.001 |
| Quality of life | | | | | | |
| SF-36 MCP (/100) | 61.2 ± 24.4 | 71.3 ± 16.6 | 17.90% | -10.1 ± 20.9 | +14.3% | 0.03 |
| SF-36 PCS (/100) | 65.9 ± 19.3 | 70.5 ± 19.9 | 11.00% | -4.6 ± 19.6 | 6.45% | 0.32 |

SD: standard deviation; CV: Coefficient of variation; MCP: Mental Component Scale, PCS: Physical Component Scale.
* *P*-values obtained from non-parametric paired Wilcoxon test.

**Table 4** Effect of training program on secondary outcomes.

| Test | Pre-test (T0) mean ± SD | Post-test (T1) mean ± SD | Inter-assay CV (%) | Mean difference ± SD | Percentage of improvement | *P*-value* |
|---|---|---|---|---|---|---|
| HADS | | | | | | |
| Anxiety | 7.57 ± 4.96 | 7.29 ± 3.2 | 22.00% | −0.28 ± 4.17 | +3.7% | 1 |
| Depression | 6.29 ± 4.89 | 4.5 ± 2.65 | | −1.79 ± 3.93 | 28.45% | 0.07 |
| Fatigue (FIS) | 63.8 ± 43.7 | 50.4 ± 33.07 | 40.60% | −13.4 ± 63.8 | +20.9% | 0.1 |
| Handgrip strength | | | | | | |
| Dominant hand (kg) | 33.1 ± 8.9 | 33.8 ± 10.4 | 5.47% | +0.7 ± 9.68 | +1.92% | 0.6 |
| Non-dominant hand (kg) | 29.9 ± 10.8 | 31.4 ± 10.4 | 5.16% | +1.5 ± 10.6 | 4.77% | 0.08 |
| NHPT | | | | | | |
| Dominant hand (seconds) | 20.4 ± 4.8 | 20.2 ± 4.48 | 4.77% | −0.2 ± 4.64 | +0.74% | 0.75 |
| Non-dominant hand (seconds) | 22.9 ± 6.36 | 21.7 ± 5.3 | 4.80% | −1.2 ± 5.85 | 5.28% | 0.02 |
| 30-seconds chair-stand test | 14.1 ± 5.12 | 16.2 ± 5.98 | 9.65% | +2.1 ± 5.57 | +13.2% | 0.002 |
| CT 65% (Watt/kg) | 1.38 ± 0.28 | 1.52 ± 0.36 | 8.71% | +0.14 ± 0.32 | +9.21% | 0.02 |

with high acceptance from the population and high overall participant's satisfaction [30,31]. In our study, even if we did not investigate directly the program overall satisfaction, we observed a high rate of adherence to the TOCT sessions (i.e. 82% of the population completed more than 80% of the training proposed sessions), while its duration was rather long (i.e. 18 weeks).

The originality of our study lies in its multi-level design. The program is addressed to patients with a polymorphic clinical presentation for whom it is usually difficult to initiate and adhere to a physical activity program, especially in the long term. Because of its design (i.e. proposal of both supervised training sessions with workshops and non-supervised walking sessions at home), the study is configured to be as close as possible to what a recovery of an adapted physical activity can look like in real life conditions and it encourages autonomy of the participants. For this reason, our study had to be unusually long (i.e. 18 weeks) in order to better reflect the future integration of adapted physical activity into patients' rehabilitation programs. With this study, the purpose was not exclusively to demonstrate the beneficial effects of the adapted physical activity on walking capacities and physical performances of patients suffering from MS. More importantly, we aimed to propose some modus operandi:

- easily applicable outside the research settings (i.e. by proposing simple exercises that can be performed at home);
- stimulating (i.e. by proposing collective work, and involving participants into personal choices of workshops, etc.) and;
- that encourages autonomy of the patients (i.e. by proposing also non-supervised walking sessions at home).

Therefore, we are convinced that our approach could easily be translated to clinical settings.

Walking limitations in patients with MS is commonly observed, with patients having slower walk, shorter stride length and more prolonged double support phase [32]. It is very encouraging to observe an improvement of all the walking tests investigated after the proposed training program in our study, both reflected by short-distance walking tests and longer-distance walking tests in which the endurance aspect is also reflected. In the literature, we identified five other open label studies using TOCT program for patients suffering from MS [30,31,33—35]. Consensually, all of these studies also found positive results on walking abilities, which confirms the potential beneficial effects of such kind of adapted training for this specific population. Only Chisari et al. [33] found moderate benefits with only a beneficial effect on short-distance walking tests such as 10-Meter Walking test and the Timed Up and Go test but not on longer-distance walking test such as the six-minute walk test. This moderate result may be explained by the very short duration (i.e. 2 weeks) of the intervention.

Supervised group exercise training has also shown to improve quality of life in patients with MS [36—38]. In our study, we were able to demonstrate a positive impact on the mental component scale of the SF-36 questionnaire, a generic quality of life questionnaire, but not on the physical component scale. Other studies using TOCT showed conflicting results in regards of quality of life with some of them demonstrating an improvement of quality of life following training and others that did not [31,33]. We could hypothesize that the use of a MS- specific health-related quality of life questionnaire could have led to different results since specific questionnaire are more sensitive to change in regards of generic tools, such as the SF-36 questionnaire. Deeper investigations deserve to be performed to objectively assess the beneficial effects of such type of training in patient's quality of life.

Results of our study also suggest an improvement of motricity and dexterity of the non-dominant hand. Manual dexterity disorders may limit the participation of patients in different activities of daily living [39]. TOCT programs also comprise several upper limb tasks, which resulted, in our study, to an improvement of the dexterity, but only for the non-dominant hand, which can be considered as a moderate result. In their 6-week single blind randomized controlled study, Ozkul et al. [35] also measure the manual dexterity using the NHPT test but failed in demonstrating improvement following their TOCT program. Because the main part of the training program is related to lower limb function (i.e. only two workshop out of 12 focused on upper limbs in our study, see Table 1), these mixed results are not surprising.

We also reported positive impact of the program on physical resistance. To our knowledge, even if the scientific literature has already largely demonstrated that resistance training increase lower limb strength resistance in MS [40], no interventional study reported the effectiveness of the intervention on lower limb physical performance, objectified with the 30-seconds chair stand test. This could be one of the original assessments in our study, since the literature is scarce on this functional aspect. Because of balance impairments, many people with MS falls frequently with an increased risk of falls-related injuries. Balance is therefore an outcome more often investigated than lower limb resistance and TOCT programs have been shown to be effective to improve body balance [31,33,35].

Finally, we also investigated the impact of the training program on cardiorespiratory resistance, showing a positive effect on this metric. These promising results deserve to be validated in controlled trials and could be used as an incentive to develop additional interventional studies.

Some limitations inherent to our methodology exist and should be highlighted. First, the study was not controlled, which is probably the main limitation to raise. Without a control group, it is difficult to separate the positive effects of the proposed training from other possible factors that may have impacted patients' evolution. As a general comment, recruitment of patients with MS accepting to be involved in physical training trials is challenging, reason why we did not recruit a control group for this pilot study. In 2017, Salci et al. enrolled 42 patients with MS in a 6-week randomized controlled trial where patients were divided in three groups: a balance training group, a lumbar stabilization group and a TOCT group. Therefore, they did not include a control group and proposed intervention to all of the participants. Results of our study should nevertheless be considered as exploratory and need to be confirmed through randomized controlled trials. To our knowledge, the study of Salci et al. [34] and the study of Ozkul et al. [35] were the only two unique existing studies using randomized controlled design with TOCT intervention in patients with MS, which demonstrates the difficulty of using such design in this population. In addition, because of the design of our study, we did not perform an a priori power calculation. The sample size is small since we included only 14 patients in our analyses, which may be not enough to demonstrate the potential effect of TOCT on various outcomes. Nevertheless, we were already able to suggest some potential benefits of TOCT with such a restricted sample. Second, because of the nature of the trial, the included patients presented, at baseline, good physical abilities compared to the spectrum of patients suffering from MS and are, therefore, may not be fully representative of the population. The external validity of our results is limited for patients suffering from more severe forms of MS. Third, only one session was supervised, the two other sessions consisting of 30 min of walking activity. Even if the adherence intended to be recorded in a diary and via a debriefing during the collective sessions, a very low prevalence of patients recorded it effectively and it is therefore impossible to have an accurate control on which sessions have effectively been performed. Third, because of the design of the TOCT, which is a heterogeneous program by definition (i.e. 12 workshops for all and then a choice of 4 workshops for each patients), we could not control exactly how much each individuals received training for strength, balance, dexterity, etc. Finally, we did not control our results for some potentially confounding factors such as nutrition, potential changes in anthropometric data following the 18-week training, even if these aspects may impact the observed modifications of physical performances of the population.

## 5. Conclusion

Despite being not controlled, this exploratory interventional pilot study highlights the feasibility and the promising effects of an adapted task-oriented circuit training combining muscle training, resistance, and cardiorespiratory exercises in a population of patient suffering from MS. However, these results deserved to be confirmed in well-conducted randomized controlled trials before drafting any strong conclusions and recommendations.

## Ethics

The study was approved by the local Ethical Committee of the CHA VIVALIA of Libramont, Belgium, by the Ehical Committee of ''Cliniques Sud-Luxembourg CSL'', Luxemburg, as well as the Ethical Committee of ''Centre

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None.

## Author contribution

OB, GD and JFK designed the study. TD and LZM collected the data. AT and CB analysed the data. OB drafted the manuscript. All authors revised and approved the final version of the manuscript.

## Disclosure of interest

The authors declare that they have no competing interest.

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