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Effect of 12-week sports intervention programme on physical fitness and sports performance in individuals with spinal cord injury

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ABSTRACT

Objectives: Inactivity in individuals with spinal cord injury (SCI) results in low physical fitness, cardiopulmonary endurance and poor quality of life. Sports participation is known to enhance physical fitness. Therefore, the present study evaluated effect of a structured, 12-week MGM Sports Intervention for Sports Intervention Program for SCI (SPISI) on physical fitness and throw-ball performance in individuals with SCI.

Materials and Methods: The study was conducted at MGM School of Physiotherapy and Spinal Cord Injury Rehabilitation centre in Navi Mumbai, India. Following ethical approval, 15 individuals with SCI (80% males and 20% females mean age 33.1 ± 7.2 years) were recruited. Upper-extremity explosive power (medicine-ball-throw), agility (*t*-test), cardiorespiratory endurance (incremental shuttle wheelchair propulsion test) and ball-throwing capacity (maximal-pass test) were evaluated pre- and post-12-week sports intervention programme (SPISI). The protocol involved strength training of upper extremity training at 50% 1 repetition maximum and participation in throw-ball sport.

Results: Following training, increase in upper extremity explosive power (11%), cardiopulmonary endurance (5%), agility (8%) and ball-throwing capacity in distance (7%) ($P < 0.05$) was observed. The large effect size was observed for sports performance (maximal-pass test distance-Cohen's d 1.261), moderate for cardiorespiratory endurance (incremental wheelchair propulsion test distance Cohen's d 0.517) and upper extremity explosive power (medicine-ball throw distance 0.593). Increment in all outcome variables was greater than minimal clinically important difference.

Conclusion: Sports intervention programme (SPISI) for 12 weeks brought about minimal clinically important difference in upper-extremity explosive power, agility, cardiorespiratory endurance and sport-specific performance and should be included as an integral component of rehabilitation of individuals with SCI.

Keywords: Spinal cord injury, Exercise intervention, Sports participation, Physical fitness, Cardiopulmonary endurance

INTRODUCTION

Individuals with spinal cord injury (SCI) develop an inactive lifestyle, which negatively influences physical fitness, social participation and quality of life.[1] Inactivity is associated with increased risk of developing secondary health problems, such as cardiovascular diseases, obesity and non-insulin-dependent diabetes mellitus due to changes in lipid profile and abnormal glucose homeostasis.[2-6] Deconditioning results in lack of optimal coordination of blood flow at rest and during exercise, altered tissue perfusion and control of blood pressure. Therefore, engagement in physical activity and monitoring physical fitness, as a predictor of cardiovascular disease risk, is imperative in individuals with SCI.[5,6]

Physical activity recommendations include ≥30 min of moderate aerobic exercise 5 day/week or ≥20 min of vigorous aerobic activity 3 days/week and strength training 2 days/week to maintain physical fitness in individuals with SCI.[7] Increased awareness of benefits of leisure time physical activity in people with SCI has led to greater engagement in sports as a complementary therapy to improve cardio-pulmonary endurance and upper extremity muscle strength.[8] Participation in sports such as weight lifting and archery has been used to achieve increment in strength of the upper extremity muscles in paraplegic patients, enabling them to gain independence in self-care activities.[8] Exergaming and heavy-bag boxing are known to provide an exercise stimulus equivalent to 3–4 Metabolic Equivalent (METS) and are recommended for health and fitness benefits.[9] Wheelchair sport such as basketball requires wheelchair propulsion and learning to pass, catch and intercept the ball, thereby developing endurance and coordination.[10] Wheelchair racing and swimming facilitate development of coordination, cardiopulmonary endurance, strength of trunk and leg muscles and weight loss.[8] Along with recognition of benefits of participation in physical activity, in the recent years, there has been an immense change in perception of society towards persons with disabilities. It has been realised that majority of persons with disabilities can lead a better quality of life if they have equal opportunities and effective access to rehabilitation measures.[1,11] Improvement in perceived quality of life, community integration, reduction in anxiety-depression, and improvement in self-esteem and self-efficacy are reported following sports participation.[12]

Throw ball is a popular game played in Asia, especially in the Indian subcontinent, and is commonly played sport at spinal cord injury rehabilitation centres. It is a non-contact ball sport played across a net between two teams of nine players on a rectangular court with no additional need for equipment. Similar to basketball, the sport demands activity of the upper extremity, agility, coordination and cardiopulmonary endurance. Hence, a Sports Intervention Programme inclusive of conventional strength training and throw ball participation was designed. The present study evaluated effect of a supervised, 12-week MGM Sports **I**ntervention for SCI (SPISI) on upper extremity explosive power, agility, cardiovascular endurance and throw-ball performance among individuals with SCI.

MATERIALS AND METHODS

The study was approved by the Institutional Ethics Review Committee, MGM Institute of Health Sciences, Kamothe, Navi Mumbai. Sample size estimation was performed using G-Power software and the present study utilised a purposive sampling method. Participants were recruited following written informed consent based on inclusion and exclusion criteria. People with level of lesion below T7 and duration since injury of more than 3 years were included (mean duration 9.4 ± 4.0 years). Patients with acute paraplegia <3 years, recent musculoskeletal, cardiopulmonary disease, metabolic illness (e.g., hypo/hyperglycaemia), psychiatric or cognitive problems and people unable to follow commands were excluded from the study.

Outcome measures

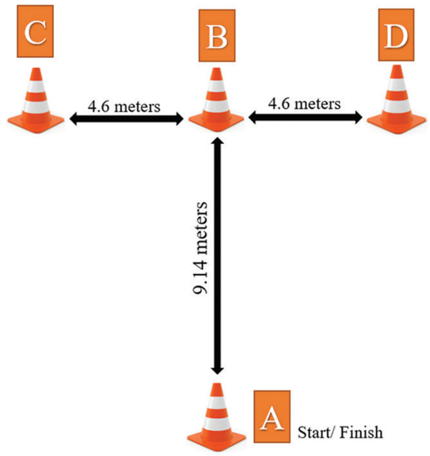
Physical fitness components relevant to throw balls such as upper limb explosive power, agility, cardiopulmonary endurance and throw-ball performance were evaluated pre- and post-12 week of SPISI programme.

Upper extremity explosive power

Upper extremity explosive was evaluated using medicine ball throw test. This test is a valid and a reliable outcome of explosive power in athletes.[13] Participants were positioned in the middle of a baseline drawn on the floor with front wheels of a locked, wheelchair behind the baseline. A 2 kg medicine ball was thrown as far as possible from this stationary position. Distance of the ball throw was measured from the starting line, in metres. Three attempts, with an interval of 2 min between each attempt, were performed and the best performance was recorded for further analysis.

Agility

Agility was evaluated using *t*-test, and the validity and reliability of this test are evaluated in wheelchair basketball players.[14,15] The participants started with the wheels of the wheelchair positioned at a distance of 0.5 m from cone A, and completed a T shaped circuit with a wheelchair using forward movements.[15] Participant moved from cone A-B (9.14 m), at comfortable speed to touch the cone with the right hand, then moved forward from B-C (4.57 m), facing forward and touching the cone C with the left hand. Further, they moved from cone C-D (14 m), to touch cone D and then from D-B (4.57 m) and back to the left to touch cone B (9.14 m). Finally, the participants had to move as quickly



as possible and return to line A. Time taken to complete the test was recorded. All participants performed the test 3 times with at least 3 min of rest between the trials. Best of three trials was considered for analysis.

Sport specific skill

Maximal pass test was used to evaluate sports specific skills. Front wheels of a locked wheelchair were positioned behind the middle centre of a baseline. Participants were instructed to pass a thrown ball as far as possible from the stationary position. The distance between the participant and the spot where the ball hit the floor was measured (in metres). The final score was the average distance of five passes.[14] The sports performance of throwball has not been robustly evaluated using objective tests. However, the sport of wheelchair basketball is more popular and has been explored by researchers to a large extent. Since, the mechanism of throwing utilised in basketball and throwball is similar; therefore, the maximal pass test was used to evaluate the sport specific skill.

Cardiopulmonary endurance

Cardiopulmonary endurance was assessed using a novel and indigenously-designed incremental wheelchair propulsion test (IWPT) over an unobtrusive, even surface, linear corridor length of 30 metres, marked with tape to provide direction from start to end of oval shaped shuttle pathway. The test was performed using a standard commonly available manual wheelchair.[16] IWPT was designed to provide gradually increasing load on the cardiopulmonary system, by increasing speed of wheel-chair propulsion from 0.7 to 2.9 m/s, over seven stages of IWPT.[17] Each stage of IWPT consisted of 4 shuttles at pre-determined speed. Metronome beats recorded on a CD, provided external pacing to the participants performing IWPT. Total duration of the test was 9.8 min. Physiological variables such as heart rate (HR), respiratory rate (RR) and blood pressure were monitored at baseline, post-test and during recovery period for 5 min. Oxygen consumption (VO_2), a gold standard outcome measure of cardiopulmonary exercise testing, was analysed using a metabolic cart, Fitmate Pro (Cosmed, Italy) through an airtight mask applied on participants' faces. Modified BORG scale was used to assess the level of exertion experienced immediately following IWPT.

Participants were instructed to propel the wheelchair from start point and reach end of the pathway at a speed indicated by pre-recorded metronome beat signal. Participants were guided by a double beat for change in phase. Objective guideline for test termination was inability to reach the start or end of the shuttle by a distance ≥1 metre for two consecutive shuttles. Subjective termination guidelines were feeling of excessive fatigue, breathlessness, muscle cramp, chest pain or excessive sweating. Participants were instructed to remain at the point of termination. Distance covered in the last lap was measured using a measuring tape. The total distance (in meters) was calculated as distance covered in full shuttles and total distance covered during the last shuttle intermittent wheelchair propulsion distance.

Intervention

The MGM Sports Intervention for SCI (SPISI) included 6 weeks of supervised sessions twice a week and 6 weeks included four supervised sessions per week [Table 1]. The warm up and cool-down sessions included diaphragmatic breathing, thoracic expansion with breathing, two repetitions

Table 1: Design of Sports Intervention Program (SPISI) for people with Spinal Cord Injury (SCI).

Frequency	Two supervised sessions per week for 0–6 weeks four supervised sessions per week for 7–12 weeks
Intensity	50% of one-repetition maximum, 10 repetitions and three sets in addition to routine training 2 min rest pause between sets, 1 min rest pause between exercises
Time	35 min/session
Warm up and cool down	Breathing exercises: Diaphragmatic breathing, thoracic expansion with breathing, wrist rolls, shoulder rolls, anterior and posterior shoulder capsule stretch, forearm flexors and extensors stretch, triceps and biceps stretch, neck stretches –10 s hold-2 repetition
Conditioning phase	Bench press, Lat pull down, Triceps Extension, Pec Deck Fly, Shoulder press and Biceps curl

each of wrist rolls, shoulder rolls, anterior and posterior shoulder capsule stretch, forearm flexors and extensors stretch, triceps and biceps stretch and neck stretches with 10 s hold. The conditioning phase included three supervised strength training sessions, during the first 3 weeks, at 50% of one-repetition maximum (1RM), three sets of 10 repetitions, with 2 min rest pause between sets, and 1 min rest pause between exercises. The next 3 weeks included four training sessions per week. Exercises included in conditioning phase were bench press, lateral pull-down, biceps curl, triceps extension, shoulder press and peck-dec fly.

1RM values were calculated using Brzycki regression equation-

1RM = 100× load repetition/(102.78–2.78× repetition)

While performing Bench press, participant was positioned on a bench with dumbbells resting on either side of lower thigh. Participant was requested to raise weights to shoulder level, position dumbbells to sides of chest with shoulder and elbow bent to 90° of abduction and flexion, respectively, with arm under each dumbbell, extend elbows and shoulders raise the dumbbell towards the ceiling, then lower the weights to the sides of their trunk until a slight stretch is felt in chest or anterior shoulder.[18]

Lateral pull-downs (with resistance band) were performed in sitting position. Participants were requested to sit up tall and engage their core by trying to pull their bellybutton towards their spine, hold the resistance band in each hand, pull hands downwards, keeping elbows wide, bring elbows towards the body, squeeze back muscles for a second and return to starting position.[18]

Bicep curl was performed in sitting position with the back firmly pushed against the backrest of the wheelchair. Participants were requested to slowly bend their elbow to lift the weight upwards against gravity, to shoulder level, then slowly lower the weight back to starting position.[18]

Triceps extension was performed in sitting with back firmly pressed against the wheelchair. Participants were requested to hold weight with both hands clasped around the dumbbell behind the head with elbows bent, straighten elbow towards ceiling, keeping arm close to head and slowly return to starting position.[18]

For shoulder press exercise, participants were requested to hold one dumbbell in each hand, bend elbows to 90°, lift arms to shoulder-level, press weights upwards over-head and straighten elbows, hold for 2–3 s, then slowly lower back to starting position.[18]

Pec-deck fly was performed by holding dumbbells close to hips in lying down position, face-up, on a bench. Dumbbells were raised straight up over the chest, palms facing together, then arms were lowered slowly to the sides, stopping when elbows were even with shoulders. This helped in protecting shoulders from excessive external rotation, one of the most vulnerable shoulder positions. Then, they completed the repetition by swinging their arms back together above chest to the starting position.[18] Duration of each session was 35 min.

Patients continued routine physiotherapy training inclusive of upper limb and lower limb strengthening, mobility and stretching exercises, trunk movements and aerobic exercises like arm jogging, performed 6 days a week for 45 min. Patients engaged in throw-ball games twice a week for 60 min. Upper extremity strengthening was not conducted on the throw-ball game days to avoid fatigue.

Statistical analysis

Statistical analysis was performed using SPSS software (version 23). Sensitivity to change estimates was based on an assumption, that change would be homogenous across the sample. Thus, distribution-based statistics including Cohen effect size (ES), standardised response mean (SRM) and paired t-test were used as data was normally distributed. Significance was set at $P = 0.05$

RESULTS

Fifteen individuals with SCI from a paraplegic rehabilitation centre in Navi Mumbai participated in the study (males-12, females-3; mean age 33.1 ± 9.4 years, height 163.7 ± 7.3 cm, weight 58.9 ± 10.7 kg, body mass index 22.2 ± 4.2 kg/m^2). American Spinal Injury Association scale was used to assess level of motor and sensory preservation of participants with 16 % (n = 5) participants categorised as grade A, 27% (n = 8) as B, 20% (n = 6) as C and 37% (n = 11) as D. Spinal cord independence measure (SCIM) was used to assess activity status of participants.[19] Moderate level of functional independence was observed, with SCIM scores of males ranging between 54 and 85 (mean score 70.6) and females between 46 and 70 (mean score 59.3). All participants were habitual indoor/outdoor wheelchair users for more than 1 year.

Following intervention, measures of physical fitness such as upper limb strength increased by 11% and agility by 8%, while maximal pass test by 17% [Table 2]. Significant cardiopulmonary stress was placed by IWPT as indicated by rise in post-test HR, RR, systolic blood pressure and VO_2 by 56, 90, 28 and 819%, respectively, thereby establishing validity of the test in measuring cardiopulmonary endurance in individuals with SCI. Participants reached 73–88% of age-related HR max during the test.

The Cohen ES was calculated as $(M2-M1)/S_b$, and SRM was calculated as (M2-M1)/S, where M2 and M1 were the mean 12-week and baseline scores, respectively; S_b was the baseline standard deviation; and S was the standard deviation of the mean change score.

Table 2: Sports fitness evaluation of 15 adults with SCI engaged in 12 weeks of sports specific intervention programme.

Fitness component	Pre mean (SD) *n*=15	Post mean (SD) *n*=15	95% Confidence interval		*P*-value
			Lower bound	Upper bound	
Cardiovascular endurance					
30 metres Incremental wheelchair propulsion test					
Distance (metres)	298 (32.73)	313.6 (35.35)	−30.71	−0.35	0.00*
VO_2 max (mL/kg/min)	15.34 (4.38)	15.41 (6.79)	−2.82	2.69	0.00*
Agility					
T-test (seconds)	31.33 (5.99)	29.26 (4.94)	1.06	3.73	0.00*
Upper limb strength					
Medicine ball throw test (Metres)	13.31 (2.93)	15.05 (2.61)	−2.27	−1.20	0.00*
Sports specific test					
Maximal pass test (Metres)	18.4 (3.06)	22.26 (2.98)	−5.06	−2.66	0.00*

SCI: Spinal cord injury, VO_2: Oxygen consumption, SD: Standard Deviation, n: Number of study participants, *Level of significance at $p<0.05$

An ES of 0.2 reflects small change, an ES of 0.5 reflects moderate change, and an ES of 0.8 reflects large change. Large change was observed for Maximal Pass test distance (Cohen's d−1.261), moderate for IWPT distance and medicine ball throw distance (Cohen's d 0.517, 0.593, respectively) and low change in agility T test (Cohen's d 0.345).

Minimal clinically important difference (MCID) values were calculated using two commonly used ES estimates in the literature: $0.3 \times S_b$ and$0.5 \times S_b$, where S_b represents standard deviation of the baseline score.

Change scores obtained from paired *t*-test analyses were compared with corresponding $0.3 \times S_b$ and $0.5 \times S_b$ MCID estimates to examine whether statistically significant differences exceeded MCID estimates for outcome measure. MCID computed for IWPT distance was 9 and 16 m, respectively, whereas observed mean change following a 12-week intervention was 16 m. Thus, indicating that IWPT was able to evaluate minimal clinically important difference satisfactorily. In addition, significant increase in propulsion distance and VO_2 post intervention demonstrated by *t*-test ($P < 0.001$) established ability of the test to identify changes in cardiopulmonary functional capacity.

MCID for medicine ball test was 0.7–1.4 whereas observed mean change was 1.79 m. Similarly, for *t*-test, MCID was 1.77–0.95 whereas actual change was 2.93 s, MCID for maximum pass test was 0.918–1.53 whereas actual change was 3.8 m, indicating that the intervention brought about clinically significant improvement in muscle strength, agility, cardiorespiratory endurance and sports performance.

DISCUSSION

The study presents effects of a 12-week sports intervention programme on physical fitness components such as upper extremity muscle strength, cardiorespiratory endurance, agility and sports performance in people with SCI.

Loss of lower limb musculature and high risk of cardiovascular disease necessitates maintenance of high level of fitness, through greater engagement in physical activities; in individuals with SCI. Efforts to engage individuals with SCI in physical activities such as sports to maintain functional capacity led to designing of sports specific throw ball intervention-SPISI. A 12-week intervention demonstrated increase in upper extremity muscle strength, agility and cardiopulmonary endurance. Improvement in upper extremity strength by training at 50% of 1RM provides a moderate intensity of stimulus which can potentially lead to increased capillarisation of skeletal muscle, thereby enabling a greater blood flow and enhanced oxidative capacity of trained muscle whereas reduces the risk of injury.[20-24] Improvement in sports specific skills was demonstrated by rise in maximal pass test results. Similar results were reported in outcomes of strength and endurance post-circuit resistance training.[25] Rapid turning, catching, throwing and manoeuvring utilised in the current protocol enhance the central neural mechanisms thereby improving agility. Similar findings are demonstrated in sprint and agility performance post-6-week explosive strength training programme in wheelchair basketball athletes.[21]

Throw-ball game demanded upper limb coordination, rapid manoeuvring of wheel chair and ball catch-throw. Engagement in bi-weekly sports sessions lasting for 1 hour provided a dynamic stimulus required to increase cardiorespiratory endurance. Wheelchair propulsion demands concentric contraction of upper extremity muscles, thereby placing a volume load on the heart, and increasing VO_2 and pulmonary demand. A study by Hasnan *et al.* also reports improvements in cardiovascular fitness post-exergaming and heavy bag boxing.[9] Literature support that heavy resistance training should be of increasing importance to enhance performance in wheelchair sports.[20] Hence, protocol of the present study can be integrated to improve sports participation in individuals with SCI.

Limitations and future scope

Limitations of the present study include a non-randomised sampling design and lack of a parallel control group. Further, a randomised and clinical trial can be undertaken to evaluate the efficacy of this intervention in a larger population.

Clinical applications

To summarise, SPISI emerged as an effective intervention bringing about moderate-large clinically relevant increase in upper extremity strength, cardiorespiratory endurance, agility and sports performance. The intervention was economical, and feasible for wide application in routine clinical settings and specialised centres for example, neurological rehabilitation centres and sports centres, to enhance fitness of individuals with SCI.

CONCLUSION

Improvement in cardiovascular endurance, upper limb strength, agility and maximal pass test established efficacy of SPISI programme in improving physical fitness of individuals with SCI. Further, longitudinal studies must be performed to observe outcomes over an extended period.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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