Novel Physiotherapies

da Silva et al., J Nov Physiother 2013, 3:2
http://dx.doi.org/10.4172/2165-7025.1000136

Research Article Open Access

# Association between the Paraplegia and Athletics Sports In The Upper Limbs, Posture and Stomatognathic System

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## Abstract

Physical or sports activities for the disabled provides an opportunity to test limits and potential, prevent secondary deformities and promote social integration of individuals. This study examined the effects of paraplegia on the posture and upper limbs in practitioners and non-practitioners of physical activities. Twenty individuals (25 to 45 years), were selected and divided into three groups: Group 1 (G1), 5 paraplegic individuals with neurological injury in the lumbar structures (L1-L5), who were not practicing any sports, Group 2 (G2), 5 paraplegic individuals with neurological injury in the lumbar structures (L1-L5) who were sports practitioners (professional athletics) and Group 3 (G3) (control group), consisting of 10 healthy individuals. The individuals were submitted to assessments utilizing biophotogrammetry following a passive referential protocol: manubrium of the sternum, acromion, lateral epicondyle of the humerus, styloid process of the radius, 7th cervical vertebra (C7) and upper and lower angles of the scapula. The evaluations were completed by scoring the postural impairment patterns according to the New York posture rating. Finally they were submitted to an electromyography, bite force and ultrasound analyses. The statistical analysis was performed utilizing ANOVA (SPSS 17.0, $p<0.05$). The biophotogrammetry shows that in shoulder a postural symmetrical pattern for all of the groups. For left and right elbow, G1 exhibited a larger loading angle; for the scapula, G1 presented a greater external rotation on the right side compared to the left side. In the New York posture rating, a greater threshold of postural changes was observed for G3. The electromyography, bite force and ultrasound images, showed that para-athletes exhibited greater changes in the functional masticatory system. The paraplegia, regardless of its association with athletic endeavors, did not lead to relevant functional changes in posture or in the upper limbs. However, observed a functional change in the performance of the stomatognathic system.

**Keywords:** Paraplegia; Biophotogrammetry; New York posture rating; Surface Electromyography; Ultrasound images; Bite force

## Introduction

Physical or sports activities for the disabled provides an opportunity to test limits and potential, prevent secondary deformities and promote social integration of individuals. The choice of activity depends on each disability, social status, opportunities, and types of limitation, sports preferences, and facilities of the means of locomotion, familiar stimulus and qualified professionals [1]. For paraplegics, the presence of postural imbalances can cause problems in the upper quadrant of the body, with possible effects on the performance of the stomatognathic system. Therefore, the physiotherapists and dental surgeons have a key role in the assessment of individuals with oral-maxillofacial disorders associated or not with postural changes [2].

The number of individuals exhibiting physical disabilities due to medullar lesions increases each day; these disabilities are mainly attributable to the high incidence of social problems, such as urban violence, automobile accidents, drug use, social exclusion, and other factors [3,4]. The participation of disabled individuals in sports is increasing and should be encouraged, as sports participation offers the possibility of experiencing sensations and movements again, which would often be impossible given the physical, social and emotional difficulties of paraplegic individuals [5]. Sports activities for the disabled provide an opportunity to test limits and potential, prevent secondary deformities, and promote social integration [6].

Health professionals are concerned with the postural and functional changes of paraplegic individuals, especially the changes related to the upper quadrant of the body because the shoulders of these individuals support a very large load articulation. This load can generate frequent pain that will affect all the developmental stages of the injury with consequent postural changes and physiological damage [7]. The conservation of stability is a dynamic process, involving a balance between stabilizing and destabilizing forces. Adaptive posture control involves modifying the motor and sensory systems in response to changes in demands from the tasks and the environment [8]. In healthy people, the maintenance of balance is an automated process that requires little attention. In individuals with spinal cord injury, this automatism is impaired, and therefore new postural control patterns emerge involving the intact parts of the sensory-motor system [9].

Bite force is a relevant factor in the ability of mastication and is directly related to the health of the masticatory system, and it is believed that, the better the system, the greater the force [10,11]. The bite force is the expression and measure of masticatory function

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**Received** April 05, 2013; **Accepted** May 06, 2013; **Published** May 08, 2013

**Citation:** da Silva GP, Ferreira B, Ferreira Gurian MB, Ribeiro AE, Verri ED (2013) Association between the Paraplegia and Athletics Sports In The Upper Limbs, Posture and Stomatognathic System. J Nov Physiother 3: 136. doi:10.4172/2165-7025.1000136

and the best measure to analyze masticatory efficiency [12]. Medical ultrasonography is an accurate and non-invasive technique used to evaluate the cross-section of the muscles and, unlike CT, which has a cumulative biological effect; it is a secure method for the dynamic muscular evaluation [13]. The thickness of the masseter and temporal muscles has been associated with occlusal factors, temporomandibular joint dysfunction, growth and facial morphology, being an important aspect to be considered in the study of the stomatognathic system [14-17].

This study examined the effects of paraplegia on the posture and upper limbs of individuals, including practitioners and non-practitioners of physical activities, utilizing computerized biophotogrammetry and the New York posture rating test, also the stomatognathic system functions, utilizing the electromyography, bite force analysis and ultrasonography, taking into account the muscular action and integrity of the stomatognathic system. The study compared paraplegic individuals with healthy individuals to identify the primary postural impairments and the effect of athletic endeavors on the maintenance of musculoskeletal structures.

## Materials and Methods

This study prospective are cross-sectional studies, in order to assess the upper limbs and postural structures caused by spinal cord injuries or athletic endeavors paraplegic individuals, to show the significant changes of musculoskeletal system and complement the knowledge about these disorders. For this purpose we used patients that practice physical activities (Athletics) of "Projeto Esporte Aplicado a Reabilitação do Deficiente Físico" of Centro Universitário Claretiano de Batatais, São Paulo, Brazil (Figure 1).

### Participants

Twenty men, aged 25 to 45 years (36.08 ± 4.32 years), were divided into three groups: Group 1 (G1-paraplegics) consisted of 5 paraplegic individuals with neurological injury in the lumbar structures (L1-L5) who were not practicing any sports, Group 2 (G2-para-athletes) consisted of 5 paraplegic individuals with neurological injury in the lumbar structures (L1-L5), who were practitioners of professional athletics and who practiced for at least one year, with all activities being performed twice a week for two hours per session; and Group 3 (G3-Control) comprised 10 healthy individuals with no motor impairment. The subjects in G2 were selected by "Projeto Esporte Aplicado a Reabilitação do Deficiente Físico" of Centro Universitário Claretiano de Batatais, São Paulo, Brazil, and the subjects of G1 and G3 were selected by Ribeirão Preto and the Batatais community, respectively. Exclusion criteria were individuals with other neurological impairments under the age of eighteen with diagnoses of postural restrictive pathologies and/or with cognitive or mental problems. For the sample calculation, we employed the program DIMAM 1.0. We performed a pilot project through the program, in which the numbers were equivalent to the number of subjects for the study. This research was approved by the Ethics Research Committee, N. 13/2010 CEP in accordance with resolution 196/96 of the Brazilian National Health Council. All of the individuals were duly informed regarding the conditions of this study and signed the informed consent.

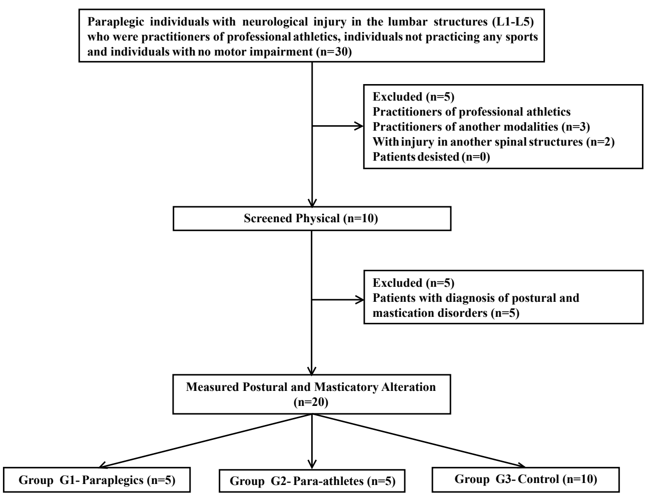


**Figure 1:** Design and flow of participants.

### Assessments tools

The participating individuals were submitted to a visual postural assessment with the G1 and G2 paraplegic individuals positioned in a wheelchair, making it possible to visualize the postural changes in a habitual position. The individuals without neuromotor impairment remained in a standing position. The individuals in G1 and G2 were positioned such that they were sitting with the hip joint and knee remaining at 90-degree angles. Each patient was instructed to remain relaxed, with the lower spine leaning along the back of the chair. For G3, the subjects were kept standing on a leveling platform, keeping a relaxed and focused gaze toward the horizon. The New York posture rating [18], was used to diagnose the postural changes associated with the adapted sports biomechanics or by the paraplegia habitual inactivity. The scale analysis parameters are 0 to 39 points (Severe Impairment), 40 to 55 points (Moderate) and more than 55 points (No Impairment). To validate the results of the postural assessment, the individuals were photographed utilizing biophotogrammetry recording patterns. This evaluation was performed with the individuals wearing trunks. To standardize the images, each subject was positioned over a three-dimensional leveling platform in front of a panel known as a simetrograph (200×100 cm×10 cm).

An entire wall-ground leveling criterion was maintained prior to positioning. A Kodak p880 camera, 8.5 megapixels, was positioned on a tripod with a 3-meter distance between the focal lenses of the camera to the central area of the individual's body. This distance was marked on the ground with gaffer's tape for further reassessment. Another measure of standardization was the tripod height, which remained at 0.90 cm between the ground and the camera's focus [19]. To delimit the angles, a passive referential was employed utilizing 25-mm-diameter polystyrene balls at the following points: manubrium of the sternum, acromion, lateral epicondyle of the humerus, styloid process of the radius, 7$^{th}$ cervical vertebra (C7), top and bottom angles of the scapula.

For the surface electromyography, twelve channels of the portable MyoSystem-BrI apparatus were used, eight channels for EMG (active and passive electrodes), four auxiliary channels, high performance signal acquisition system and software for control, storing and processing and analysis of data. Connectors have a CC input voltage of ± 12V @ ± 100 mA, CMRR (common-mode rejection ratio) of 112 dB @ 60 dB, input impedance for passive electrodes of $10^{10}$ Ohms/6 pf, input bias current for active electrodes of ± 2 nA, protection against overvoltage and band pass filters of 5Hz to 5KHz to cancel out noise. Simple differential active electrodes were used (two 10 mm long and 1mm wide silver-chloride bars , separated by a distance of

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10 mm) and fixed in a resin capsule measuring 40×20×5 mm. The electrodes were positioned in the following muscles: The muscles were: Right and Left Temporal (RT and LT), Right and Left Masseter (RM and LM) and Right and Left sternocleidomastoid (RS and LS). The subject was asked to perform voluntary contraction to position the electrodes according to the recommendations made by Cram [20]. The EMG signals of the masticatory muscles were acquired during the postural maintenance positions (rest, protrusion, right laterality (RL) and left laterality (LL) in the following clinical conditions: rest and maximum voluntary contraction for 4 seconds (normalization factor); protrusion, RL and LL with maximum dental contact for 10 seconds. All electromyographic activities were was normalized by maximum voluntary contraction.

The EMG signals were acquired in a calm and quiet place while the individual sat in a comfortable chair maintaining and an erect position with his feet on the ground and hands resting on the thighs. The head was up so the chin was parallel to the ground. Necessary instructions and explanations were given previously so that the individual would remain calm and breathe slowly.

For the analysis of muscle thickness, the SonoSite Titan ultrasound system was used. It was nationalized with 56 mm linear transducer of 10 MHz. Ultrasound imaging were collected from the Right and Left Temporal (RT and LT) and Right and Left Masseter (RM and LM), at rest and dental clenching in Maximum Habitual Intercuspal (MHI). The linear transducer was positioned across the direction of the muscle fibers. The target location was confirmed by a muscle palpation and the transducer movement to obtain an optimized image.

During the examination, the individuals sat back, without fixing the head. Measurements were performed directly on the image at the time of their acquisition, with an accuracy of 0.1 mm. Three examinations were carried out in each muscle condition (rest and dental clenching in maximum habitual intercuspal) with an interval of two minutes between each measurement.

The bite force readings were performed after the electromyography examinations. Maximum bite force was measured utilizing a digital dynamometer (model IDDK; Equipamentos Industriais Ltd., Taboão da Serra, SP, Brazil) with capacity of 100 kgf and adapted to oral conditions. This equipment has a scale in kgf or N and a “set zero” button that allows an accurate control of the obtained values, and also provides the “peak” record. This appliance comprises a bite fork, which consists of two metal rods with plastic covering. The bite fork is placed between the subject’s teeth and held by the operator at the moment of maximum bite force reading. Its high-precision load cell and electronic circuit for indication of force provide accurate measurements that are easy to read from its digital three-liquid crystal screen.

Assessments were made in the right and left first molar regions, which is where we exert greater bite force [21]. The bite force measures were collected with each individual sitting in a chair with his arms positioned along the body and hands resting on the thighs. The dynamometer was cleaned with alcohol after each use and disposable latex finger cots (Wariper-SP, São Paulo, SP, and Brazil) were positioned on the biting arms as a biosecurity measure. Each individual was asked to bite on the device 3 times with maximum effort, alternating sides (left and right) with a 2-min rest between trials. Bite force was recorded in kgf. The highest out of three records was regarded as the maximal bite force [22,23].

## Data analysis

The images were obtained by a single observer without zoom and in three delimitation planes: anterior, posterior and lateral. Finally, the four sides were traced through the ImageJ 1.4.3.67 software with references to the areas in the shoulder, elbow and scapula. The data were tabulated, and an ANOVA (SPSS 17.0) among the three groups was performed at p<0.05.

The electromyography signals were processed in the Myosystem-Br1 version 3.56. After scanning, the analog signals were amplified (with a gain of 1000x), filtered (band-pass filter of 0.01 to 1.5 kHz) and sampled by a converter board A/D with 12 bits acquisition frequency of 2 KHz.

The EMG data normalized, bite force and muscle thickness measurements, were tabulated and statistically analyzed utilizing SPSS version 17.0 for Windows (SPSS Inc., Chicago, IL, USA). We performed a descriptive analysis (means, standard deviations, maximum and minimum values) for each variable. The values obtained were compared by analysis of variance (ANOVA).

## Results

The computerized biophotogrammetry showed that the values were similar among the three groups with a symmetrical postural pattern related to the shoulder elevation and depression. For the variable elbow, G1 was observed to exhibit a larger loading angle compared with G2 and G3. However, G2 also presented a greater loading angle compared with G3. For the scapula, G1 was verified as presenting greater external rotation of the scapula on the right side, but in G2 and G3, the left side was predominant. These results were statistically significant only for the right elbow among the three groups (Table 1).

The New York posture rating chart showed that G3 presented greater levels of postural impairment compared with the other groups, and G2 showed the lowest values. All of the groups were classified with moderate postural impairment (Table 2).

| Region | Groups | N. of individuals | Mean | Standard Deviation | Sign. |
|---|---|---|---|---|---|
| Right shoulder | G1 | 05 | 104.39 | ± 3.10 | $0.44^{ns}$ |
| | G2 | 05 | 99.55 | ± 1.36 | |
| | G3 | 10 | 101.60 | ± 2.00 | |
| Left shoulder | G1 | 05 | 100.03 | ± 2.37 | $0.96^{ns}$ |
| | G2 | 05 | 99.24 | ± 1.54 | |
| | G3 | 10 | 99.65 | ± 1.49 | |
| Right elbow | G1 | 05 | 150.79 | ± 4.53 | $0.26^{ns}$ |
| | G2 | 05 | 154.41 | ± 2.40 | |
| | G3 | 10 | 158.47 | ± 2.78 | |
| Left elbow | G1 | 05 | 150.87 | ± 3.19 | 0.01* |
| | G2 | 05 | 157.80 | ± 4.07 | |
| | G3 | 10 | 165.17 | ± 2.69 | |
| Right scapula | G1 | 05 | 128.45 | ± 2.03 | $0.13^{ns}$ |
| | G2 | 05 | 116.97 | ± 4.73 | |
| | G3 | 10 | 125.57 | ± 3.05 | |
| Left scapula | G1 | 05 | 119.42 | ± 6.66 | $0.18^{ns}$ |
| | G2 | 05 | 130.78 | ± 4.57 | |
| | G3 | 10 | 121.95 | ± 2.08 | |

*Statistic significance for p ≤ 0.05
$^{ns}$Not significant

**Table 1:** Mean values and standard deviation of computerized biophotogrammetry in paraplegic individuals (G1), para-athletes (G2) and control (G3) (ANOVA p<0.05).

| Group | Sign. | Mean | Standard Deviation |
|---|---|---|---|
| G1 | 0.72$^{ns}$ | 43.40 | ± 4.26 |
| G2 | | 44.20 | ± 2.47 |
| G3 | | 41.60 | ± 1.39 |

$^{ns}$Not significant

**Table 2:** Mean values and standard deviation of New York posture rating chart in paraplegic individuals (G1), para-athletes (G2) and control (G3) (ANOVA p<0.05).

| Muscles | Groups | Mean | Standard Error | Sign. |
|---|---|---|---|---|
| Right Temporal | G1 (Paraplegics) | 0.032 | ± 0.009 | 0.04* |
| | G2 (Para-athletes) | 0.095 | ± 0.037 | |
| | G3 (Control) | 0.035 | ± 0.005 | |
| Left Temporal | G1 (Paraplegics) | 0.036 | ± 0.009 | 0.07$^{ns}$ |
| | G2 (Para-athletes) | 0.081 | ± 0.027 | |
| | G3 (Control) | 0.036 | ± 0.005 | |
| Right Masseter | G1 (Paraplegics) | 0.064 | ± 0.022 | 0.20$^{n}$ |
| | G2 (Para-athletes) | 0.114 | ± 0.044 | |
| | G3 (Control) | 0.048 | ± 0.014 | |
| Left Masseter | G1 (Paraplegics) | 0.062 | ± 0.024 | 0.31$^{ns}$ |
| | G2 (Para-athletes) | 0.098 | ± 0.012 | |
| | G3 (Control) | 0.055 | ± 0.017 | |
| Right SCM | G1 (Paraplegics) | 0.406 | ± 0.168 | 0.64$^{ns}$ |
| | G2 (Para-athletes) | 0.575 | ± 0.158 | |
| | G3 (Control) | 0.460 | ± 0.063 | |
| Left SCM | G1 (Paraplegics) | 0.479 | ± 0.325 | 0.97$^{ns}$ |
| | G2 (Para-athletes) | 0.493 | ± 0.135 | |
| | G3 (Control) | 0.530 | ± 0.072 | |

*Statistical significance at p ≤ 0.05
$^{ns}$Not significant

**Table 3:** Electromyographic means (µV) and standard error of right and left temporal, right and left masseter and right and left sternocleidomastoid muscles in paraplegic individuals (G1), para-athletes (G2) and control (G3), for the rest clinical condition (ANOVA for *p*<0.05).

| Muscles | Groups | Mean | Standard Error | Sign. |
|---|---|---|---|---|
| Right Temporal | G1 (Paraplegics) | 0.045 | ± 0.013 | 0.02* |
| | G2 (Para-athletes) | 0.225 | ± 0.068 | |
| | G3 (Control) | 0.076 | ± 0.031 | |
| Left Temporal | G1 (Paraplegics) | 0.063 | ± 0.021 | 0.00* |
| | G2 (Para-athletes) | 0.142 | ± 0, 028 | |
| | G3 (Control) | 0.063 | ± 0.007 | |
| Right Masseter | G1 (Paraplegics) | 0.643 | ± 0.501 | 0.62$^{ns}$ |
| | G2 (Para-athletes) | 0.514 | ± 0.229 | |
| | G3 (Control) | 0.326 | ± 0.058 | |
| Left Masseter | G1 (Paraplegics) | 0.476 | ± 0.265 | 0.80$^{ns}$ |
| | G2 (Para-athletes) | 0.555 | ± 0.098 | |
| | G3 (Control) | 0.417 | ± 0.094 | |
| Right SCM | G1 (Paraplegics) | 1.480 | ± 0, 432 | 0.64$^{ns}$ |
| | G2 (Para-athletes) | 1.040 | ± 0.232 | |
| | G3 (Control) | 1.453 | ± 0.297 | |
| Left SCM | G1 (Paraplegics) | 0.802 | ± 0.245 | 0.43$^{ns}$ |
| | G2 (Para-athletes) | 1.180 | ± 0.335 | |
| | G3 (Control) | 1.737 | ± 0.549 | |

*Statistical significance at p ≤ 0.05
ns Not significant

**Table 4:** Electromyographic means (µV) and standard error of right and left temporal, right and left masseter and right and left sternocleidomastoid muscles in paraplegic individuals (G1), para-athletes (G2) and control (G3), for the protrusion clinical condition (ANOVA for *p*<0.05).

The electromyography analysis at rest, it was observed that in G2 the temporal and masseter muscles were the most active. There was also hyperactivation of the sternocleidomastoid muscles for all analyzed groups (Table 3). Data were only statistically significant for the right temporal muscle (ANOVA for p<0.05).

In protrusion, there was a standard of normality for all analyzed groups, with the masseter muscles being more active than the temporal, with higher values in groups G1 and G2. G2 presented the highest temporal muscle activation values. The sternocleidomastoid muscles for all groups were activated (Table 4). The data was significant for the right and left temporal muscles (ANOVA for p<0.05).

In right laterality, the activation of the right temporal muscles was higher in all analyzed groups. For the masseter muscles, G1 and G3 had pattern values, with the left masseter being more active than the right. For the sternocleidomastoid muscles, G1 presented greater activation of the right side compared with the left and G2 had similar pattern values. In G3, the left side was more activated than the right (Table 5). The data was only significant for the right masseter muscle (ANOVA for p<0.05).

In left laterality as expected, the activation pattern of the left temporal muscles were more active that the right muscles. The masseter muscles presented similar pattern in both sides. The left sternocleidomastoid muscles remained more active (Table 6). These results were only statistically significant for the right masseter and temporal muscles among the three groups (ANOVA for p<0.05).

In the assessment of muscle thickness (ultrasound), G1 presented greater thickness for the masseter muscles at rest. In MIH, G1 had greater thickness for the temporal muscles. There was no statistically significant difference between the groups, in none of the evaluated muscles (p<0.05–ANOVA) (Table 7).

For the left and right maximum molar bite forces, G2 G3 had the lowest force threshold presented greater bite force threshold when compared with the other groups. G3 had the lowest force threshold (Table 8). Data were not statistically significant between the groups (ANOVA for p<0.05).

| Muscles | Groups | Mean | Standard Error | Sign. |
|---|---|---|---|---|
| Right Temporal | G1 (Paraplegics) | 0.248 | ± 0.174 | 0.13$^{ns}$ |
| | G2 (Para-athletes) | 0.286 | ± 0.058 | |
| | G3 (Control) | 0.077 | ± 0.011 | |
| Left Temporal | G1 (Paraplegics) | 0.039 | ± 0.007 | 0.06$^{ns}$ |
| | G2 (Para-athletes) | 0.092 | ± 0.034 | |
| | G3 (Control) | 0.039 | ± 0.004 | |
| Right Masseter | G1 (Paraplegics) | 0.139 | ± 0.040 | 0.00* |
| | G2 (Para-athletes) | 0.702 | ± 0.229 | |
| | G3 (Control) | 0.124 | ± 0.035 | |
| Left Masseter | G1 (Paraplegics) | 0.218 | ± 0.087 | 0.45$^{ns}$ |
| | G2 (Para-athletes) | 0.304 | ± 0.089 | |
| | G3 (Control) | 0.184 | ± 0.045 | |
| Right SCM | G1 (Paraplegics) | 3.064 | ± 1.328 | 0.17$^{ns}$ |
| | G2 (Para-athletes) | 1.975 | ± 0.526 | |
| | G3 (Control) | 1.317 | ± 0.215 | |
| Left SCM | G1 (Paraplegics) | 0.912 | ± 0.361 | 0.59$^{ns}$ |
| | G2 (Para-athletes) | 2.009 | ± 0.788 | |
| | G3 (Control) | 1.783 | ± 0.676 | |

*Statistical significance at p ≤ 0.05
$^{ns}$Not significant

**Table 5:** Electromyographic means (µV) and standard error of right and left temporal, right and left masseter and right and left sternocleidomastoid muscles in paraplegic individuals (G1), para-athletes (G2) and control (G3), for the right laterality clinical condition (ANOVA for p<0.05).

| Muscles | Groups | Mean | Standard Error | Sign. |
|---|---|---|---|---|
| Right Temporal | G1 (Paraplegics) | 0.038 | ± 0.170 | 0.00* |
| | G2 (Para-athletes) | 0.041 | ± 0.016 | |
| | G3 (Control) | 0.047 | ± 0.004 | |
| Left Temporal | G1 (Paraplegics) | 0.255 | ± 0.140 | 0.40ns |
| | G2 (Para-athletes) | 0.267 | ± 0.103 | |
| | G3 (Control) | 0.134 | ± 0.035 | |
| Right Masseter | G1 (Paraplegics) | 0.211 | ± 0.075 | 0,04* |
| | G2 (Para-athletes) | 0.326 | ± 0.092 | |
| | G3 (Control) | 0.120 | ± 0.022 | |
| Left Masseter | G1 (Paraplegics) | 0.204 | ± 0.130 | 0.32ns |
| | G2 (Para-athletes) | 0.393 | ± 0.169 | |
| | G3 (Control) | 0.170 | ± 0.056 | |
| Right SCM | G1 (Paraplegics) | 1.200 | ± 0.601 | 0.95ns |
| | G2 (Para-athletes) | 1.044 | ± 0.271 | |
| | G3 (Control) | 1.084 | ± 0.239 | |
| Left SCM | G1 (Paraplegics) | 2.795 | ± 1.757 | 0.91ns |
| | G2 (Para-athletes) | 2.672 | ± 1.559 | |
| | G3 (Control) | 2.208 | ± 0.556 | |

*Statistical significance at $p \leq 0.05$
nsNot significant

**Table 6:** Electromyographic means (μV) and standard error of right and left temporal, right and left masseter and right and left sternocleidomastoid muscles in paraplegic individuals (G1), para-athletes (G2) and control (G3), for the left laterality clinical condition (ANOVA for *p*<0.05).

| Muscles | Groups | Clinical Condition | Mean | Standard Error | Sign |
|---|---|---|---|---|---|
| Right Temporal | G1 (Paraplegics) | Rest | 0.622 | ± 0.042 | 0.18ns |
| | G2 (Para-athletes) | | 0.710 | ± 0.038 | |
| | G3 (Control) | | 0.641 | ± 0.020 | |
| | G1 (Paraplegics) | MIH | 0.768 | ± 0.035 | 0.85ns |
| | G2 (Para-athletes) | | 0.740 | ± 0,042 | |
| | G3 (Control) | | 0.751 | ± 0.022 | |
| Left Temporal | G1 (Paraplegics) | Rest | 0.680 | ± 0.035 | 0.20ns |
| | G2 (Para-athletes) | | 0.590 | ± 0.043 | |
| | G3 (Control) | | 0.618 | ± 0.021 | |
| | G1 (Paraplegics) | MIH | 0.776 | ± 0.025 | 0.15ns |
| | G2 (Para-athletes) | | 0.680 | ± 0.034 | |
| | G3 (Control) | | 0.739 | ± 0.026 | |
| Right Masseter | G1 (Paraplegics) | Rest | 1.252 | ± 0.075 | 0.24ns |
| | G2 (Para-athletes) | | 1.166 | ± 0.102 | |
| | G3 (Control) | | 1.072 | ± 0.058 | |
| | G1 (Paraplegics) | MIH | 1.516 | ± 0.055 | 0.57ns |
| | G2 (Para-athletes) | | 1.452 | ± 0.101 | |
| | G3 (Control) | | 1.404 | ± 0.082 | |
| Left Masseter | G1 (Paraplegics) | Rest | 1.118 | ± 0.067 | 0.79ns |
| | G2 (Para-athletes) | | 1.042 | ± 0.095 | |
| | G3 (Control) | | 1.088 | ± 0.055 | |
| | G1 (Paraplegics) | MIH | 1.430 | ± 0.062 | 0.76ns |
| | G2 (Para-athletes) | | 1.360 | ± 0.079 | |
| | G3 (Control) | | 1.374 | ± 0.090 | |

nsNot significant

**Table 7:** Ultrasonographic means of the right (RT) and left (LT) temporal muscles and right (RM) and left (LM) masseter muscles for paraplegic individuals (G1), para-athletes (G2) and control (G3) of the rest and MIH clinical conditions.

## Discussion

The participation of people with disabilities in sports activities provides opportunities for them to enjoy sensations and movements, which were not possible due to their motor impairment. These activities help persons with disabilities acquire social skills and promote social-emotional development. Adapted physical activity is recommended to anyone with physical impairment as it provides individuals with the spirit of challenge [5]. According to Sack et al. [1], physical activity or sports for the disabled provides an opportunity to test the limits and potential, preventing secondary deformities and promote the social integration of the individual.

| Side | Groups | Mean | Standard Error | Sign |
|---|---|---|---|---|
| Right | G1 (Paraplegics) | 40.04 | ± 13.94 | 0.70ns |
| | G2 (Para-athletes) | 48.27 | ± 12.71 | |
| | G3 (Control) | 36.86 | ± 5.87 | |
| Left | G1 (Paraplegics) | 39.44 | ± 16.78 | 0.77ns |
| | G2 (Para-athletes) | 45.94 | ± 12.65 | |
| | G3 (Control) | 35.84 | ± 4.91 | |

nsNot significant

**Table 8:** Left and right maximum molar bite forces for paraplegic individuals (G1), para-athletes (G2) and control (G3).

The increase in urban violence, traffic accidents and armed robbery has resulted in many cases of paraplegia in the population. This impairment generally affects young single males living in urban areas. Motor or sensory functions can be impaired partially or totally, and vasomotor, intestinal, vesicle and also sexual dysfunctions can occur. According to the Jung et al. [24], the greatest impairment of individuals involves the quality and perception of their new reality in the context of their culture and values. The rehabilitation of these individuals includes physical health, improvement of their independence levels and psychological state, and promotion of their social relationships and spiritual patterns [25].

Participation in sports provides paraplegic individuals with an opportunity to enjoy sensations and movements that previously were not possible due to the person's motor, social and emotional states. The history of adapted sports dates from ancient times, although after World War II, these activities received more attention in the areas of rehabilitation, prevention and the formation of organizations, due to the growing disabled population [26]. The practice of sports-related activities is indicated for anyone with physical impairment because these activities provide the individuals with competitive spirit [5]. The physical or sports activity provides the disabled individuals an opportunity to test their limits and potential, to prevent secondary deformities and to promote their social relationships. The choice of activities depends on the disability, the social status of the individual, their opportunities, and type of limitation, their sports preferences, transportation facilities, family support and professional coaching to prepare the athletes [6].

Paraplegia affects the motor and sensory sensations depending on the region of the injury. Through a systematic examination of dermatomes and myotomes, the medullar segment affected by the spinal cord injury can be determined. In paraplegia, the ability to create voluntary muscle contraction, motor coordination and range of motion are hindered [27]. Paraplegia and/or quadriplegia represent motor limitations, which range from simple difficulties to total dependence in performing basic daily activities. One of the main impairments of a central nervous system (CNS) injury is the functional disability of spasticity, which is one of the leading causes of functional impairment [28]. Spasticity generates a decrease in the arch of movement and consequently affects postural and functional skills [29].

Computerized biophotogrammetry is a tool used to determine functional and physical diagnoses in many different health areas. This tool has been used in many studies, which demonstrated its validity. The technique is based on the photogrammetric principle of photographic images obtained from body movements. Biophotogrammetry is a noninvasive evaluation resource that has the advantage of being effective in its clinical application. This method is also a low-cost, highly accurate resource and offers reproducible results. For postural evaluation, the individuals were submitted previously to demarcations of anatomical reference points, which correspond to the angles and allow good quality images to be captured, allowing an adequate photogrammetric interpretation [19]. In this study, the individuals were positioned in a standard posture, with G1 and G2 corresponding to a sitting position and G3 in a standing position, such that three axes for the analysis of the upper limbs were used: shoulder, elbow and scapula. For the shoulder, the purpose was to observe the impairment threshold of shoulder elevation and depression utilizing angular points. The study found that the right shoulder presented an elevation only for G1 and remained symmetrical for the other groups. This postural change could be directly associated with the use of a wheelchair and also with the dominant hand of the individuals. G2 did not exhibit an elevation of the shoulder. This finding could be due to the efficiency of the joint dynamic stabilizers that allowed greater sustainability to be derived from the sports activity. In G3, the body load distribution was homogeneous as the individuals maintained their standing position.

An analysis of the elbow postural axis was used to visualize the flexion angle. All the groups presented a greater loading angle in the right elbow, emphasizing that all the individuals of the three groups were right handed, and therefore their usual activities demanded a greater performance from repeated action in the elbow region. In the analysis of the scapula postural axis, the objective was to observe the external rotation threshold of the scapula. Only G1 presented greater impairment of the external rotation on the right side associated with the right shoulder, showing a generalized impairment of the scapula-humeral complex in the G1 individuals, possibly related to a deficiency of the joint dynamic stabilizers. In the other groups, the prevalence of the scapula external rotation on the left, which was also related to a deficit of the scapula's dynamic stabilizers, was observed because these individuals were right handed and maintained a reduced demand level from the left bone.

The New York posture rating is an assessment screening tool used to compare the static posture to a special chart to define the postural level that corresponds to the individual [18]. The study found a higher prevalence of postural impairment in G3. This result was unexpected, considering that G3 was the control group, but the outcomes were worse compared to normal posture.

The study of the stomatognathic system for the disabled , athletes or not, compared with healthy individuals can contribute to the advances of knowledge on the action of the masticatory muscles to explain how they are affected by the lesion of the spinal cord associated with the benefits of sport.

Currently, the surface electromyography (SEMG) is considered much more than an additional technique to the anatomical, physiological and neurophysiological study of skeletal muscle system. It has become a diagnostic tool, easy to apply, with a good level of comfort and does not interfere with the muscle activation patterns [11].

In the present study, electromyography analyses were carried out with paraplegics (G1), para-athletes (G2) and control (G3) used to evaluate the bilateral EMG activity patterns of masseter, temporal and sternocleidomastoid muscles at rest, and in different clinical conditions to investigate postural changes in muscle activation function due to paraplegia.

The muscles at rest do not present contraction of motor units and therefore do not show myoelectric activity [30,31], although some authors have found minimal electrical activity in the muscles associated with the chewing process [21,32]. At rest, the muscles present a state of passive resistance to stretching of the fibers; consequently the stimuli arrive at their traction units (nerve and muscle fibers) that excite alternately to avoid fatigue. This occurs by means of automatic and unconscious myotatic reflexes, keeping the jaw in anti-gravitational position [33]. The EMG activity during rest for the analyzed muscles on both sides, in three groups, showed that maintaining this postural condition required the activation of muscle fibers in all muscles with the masseter and esternocleidomastoid muscle activity being well defined, especially in individuals in G2. No higher activation of the temporal muscles was observed in any of the groups. These results are in disagreement with Cecilio [11], who have verified that for healthy individuals from all age groups, there was greater temporal muscle activation at rest. This is justified by the function of the temporal muscles in mandibular position.

In protrusion, all groups showed a typical contraction pattern to keep the position, consisting of greater activation of the masseter muscles when compared with the temporal muscles [11], and in these muscle groups , higher values were observed in groups G1 and G2. During the lateral movement of the mandible, there is a neuroanatomical pattern of muscle activation in which that there must be greater EMG activity in temporal muscle on the same side of the mandible which stretches alongside the workplace (functional), while for the muscle masseter greater contralateral muscle activity is expected [11,21,34]. This activation pattern was observed in groups G1 and G3 in right laterality; in left laterality, all the groups presented standardized activity for the temporal muscles, but not for the masseter muscles.

It is relevant to observe that the data analyzed in this study showed that the human body is continuously affected by processes that promote physiological alterations, and functional changes have occurred in the stomatognathic system action because of paraplegia and para-athletic practice.

In the present study, the images of masseter and temporal muscles, obtained through the ultrasound were well defined and allowed to determine their thicknesses. This technique does not expose people to radiation, so it is safe, quick and reproducible, and also considered to be suitable for the evaluation of the muscles of the face. It should be emphasized that, in order to obtain correct images, without discrepancies, the transducer should be well positioned, especially in longitudinal studies [35]. Benington [36] observed that several factors can provide erroneous muscle measurements, for example: sample type, transducer position for capturing the images and the technique used by different professionals. According to Bertram [13], for the ultrasound exam, the position of the transducer should be determined by palpation of the muscles at rest and during contraction.

In the study, it was found that the thickness of the masseter and temporal muscles of the paraplegic individuals and para-athletes was similar to that of individuals without neuromotor impairment (G3). Although the sport activity was related to muscle trophism as a result of the training program carried out, our results showed that the effect was not the same for adjacent muscles (muscles of the stomatognathic system).

Bite force is an important factor for the knowledge of the maxilla and the mandible and one of the most important factors to control this force is the periodontium sensory mechanism. During the maximum bite force evaluation, the subjects were well instructed and collaborated with the experiment, with the methodology standards and three repetition performances, with a two minute interval between them, to obtain the maximum bite force, minimizing errors and interferences. A digital dynamometer, with capacity up to 100 Kgf, was used and adapted to oral conditions. It consists of two metal rods with plastic covering. The bite force is placed between the subject's teeth and held by the operator at the moment of maximum bite force reading. Its high-precision load cell and electronic circuit for indication of force provide accurate measurements that are easy to read from its digital three-liquid crystal screen.

The diameter of both rods measures approximately 10 mm and it is appropriate to ensure a mouth opening that does not interfere in the force employed, avoiding muscle stretching and the exaggerated displacement of the condyles [33,37]. With regard to maximum molar bite force, it was found that individuals from groups G1 and G2, paraplegics and para-athletes have greater force than the controls for both sides, and the bite force of G2 was greater. This result showed that the practice of physical activities interfered directly in the muscle function of the stomatognathic system.

Based on the results obtained in this study, it can be concluded that paraplegia, whether associated or not with athletic endeavors, does not promote relevant functional changes in posture and in the upper limbs. However, promoted functional changes in the stomatognathic system function. This fact may be related to the monitoring of all paraplegic individuals by physiotherapists. Among the groups in this study, the paraplegics who practiced athletics presented major postural impairment and upper limb disorders compared with the other groups; however, these findings were not statistically relevant.

## Acknowledgements

Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP)- (Process: 2010/07507-5).

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**Citation:** da Silva GP, Ferreira B, Ferreira Gurian MB, Ribeiro AE, Verri ED (2013) Association between the Paraplegia and Athletics Sports In The Upper Limbs, Posture and Stomatognathic System. J Nov Physiother 3: 136. doi:10.4172/2165-7025.1000136