Motriz, Rio Claro, v. 32, 2026, e10241892 DOI: http://dx.doi.org/10.5016/s1980-6574e10241892

Acute and Chronic Effects of Exercise in Health

Wrist muscle function, pain level and performance in cheerleaders with and without wrist pain: clinical relevance and statistical significance

Cristiano Carvalho[1,2,3], Beatriz Cardinal Prando[1], Marina Petrella[1], Giovanna Camparis Lessi[4], Paula Regina Mendes da Silva Serrão[1]

[1]Universidade Federal de São Carlos, Departamento de Fisioterapia, São Carlos, SP, Brazil; [2]Universidade Federal de São Paulo, Departamento de Biociências, Santos, SP, Brazil; [3]Universidade Estadual da Paraíba, Departamento de Fisioterapia, Campina Grande, PB, Brazil; [4]Afya Centro Universitário UNIMA, Maceió, AL, Brazil.

Associate Editor:Fábio F.B. Carvalho, Instituto Nacional de Câncer José Alencar Gomes da Silva, Rio de Janeiro, RJ, Brazil. E-mail: fabiofbcarvalho@gmail.com.

Abstract - Objectives: To compare wrist muscle strength, grip strength and electrical activity of the flexor digitorum superficialis (FDS), flexor carpi ulnaris (FCU) and extensor carpi ulnaris muscles between cheerleaders with and without wrist pain as well as investigate pain and compromised performance regarding the sport and activities of daily living (ADLs). **Methods:** This is cross-sectional study evaluated wrist and hand muscle capacity using an isokinetic dynamometer and handgrip dynamometer. Electrical muscle activity was captured during the strength evaluations. Pain at rest, post-training pain and impaired physical function during the sport and ADLs were evaluated using a scale and questionnaire. **Results:** Twenty-two cheerleaders participated in the study (11 with pain - symptomatic group [SG] and 11 without pain - control group [CG]). Statistically significant and clinically relevant differences between groups were found regarding total work during wrist extension in the concentric mode activity (CG: 13.5 ± 21.2 vs SG 6.6 ± 2.3; $p = 0.05$), activation of the FDS (CG: 57.0 ± 30.9 vs SG 31.8 ± 10.8; $p = 0.03$) and FCU (CG: 48.0 ± 18.5 vs SG 30.7 ± 16.8; $p = 0.03$) muscles during isokinetic evaluation of concentric peak torque of wrist flexion, activation of the FDS (CG: 121.5 ± 55.3 vs SG 65.3 ± 19.7; $p = 0.005$) and FCU (CG: 94.0 ± 35.9 vs SG 63.0 ± 32.4; $p = 0.046$) muscles during isokinetic evaluation of concentric total work of wrist flexion, pain intensity at rest (CG: 0 [0] vs SG 0.5 [2.0];$p = 0.006$) and after training (CG: 0 [0] vs SG 6.3 [2.5];$p < 0.001$) and degree of impairment regarding sport (CG: 8.2 ± 6.4 vs SG 16.3 ± 8.5; $p = 0.02$) and ADLs (CG: 14.8 ± 1.8 vs SG 46.0 ± 16.8; $p < 0.001$). Cheerleaders with wrist pain exhibited greater impairments. **Conclusion:** Cheerleaders with wrist pain exhibit compromised muscle function of the wrist and hand as well as upper limb impairment during the practice of the sport and the performance of activities of daily living.

Keywords: athletes, electromyography, hand strength, muscle strength dynamometer, sports, strength muscle..

Introduction

Cheerleading has existed for more than a century, and its main purpose is to lead people to cheer for sports teams[1-3]. This activity has gradually transformed into a legitimate sport involving dance movements, acrobatics, complex gymnastic maneuvers and stunts performed as a group[4]. The three main cheerleading positions for the formation of a stunt are the base, flyer and spotter[5]. The execution of stunts can place considerable load on some joints and can cause injuries[6].

In an epidemiological study, Shields & Smith[7] found that the majority of upper limb injuries in cheerleaders occur in the wrists and hands. The most common injuries are pulled muscles, sprains, abrasions, contusions, bruises and dislocations due to the movements of holding the flyer during the dismounting of the stunt, failure to complete the maneuver, during the lifting of the flyer, when tossing the flyer into the air or during the occurrence of a fall[5,6,8]. Data from a prevalence study addressing injuries in cheerleaders in Brazil reveal that the upper limb is the most affected, corresponding to 41% of injuries, with the wrist corresponding to 14.8%[9].

According to Gaston and Loeffler[10], the practice of competitive sports and athletic training on the amateur level place the hands and wrists at risk of injury, with up to 25% of all athletic injuries affecting these segments (fractures of the bones of the hand and wrist and dislocations). The authors also state that the high impact, repetitive strain, axial load and rotational forces in gymnasts and cheerleaders result in a variety of wrist and hand injuries[10]. Nonspecific pain in the wrist is also commonly found in these athletes. In cheerleaders, especially those in the base position, the load on the wrist is constant due to the need to secure the flyer's feet during the formation of a stunt and support the flyer's weight[5]. Moreover, the wrist and hand are susceptible to axial loading during some movements, such as tumbling maneuvers.

Pain sensitizes capsule mechanoreceptors, which send signals to inhibitory interneurons in the spinal cord[11,12]. These interneurons inhibit alpha motor neurons and, consequently, the signals that would be transmitted to the wrist flexors and extensors[11,12]. This phenomenon is denominated arthrogenic muscle inhibition, which is generated by abnormal afferent information from the affected joint, resulting in the diminished activation and/or weakness of periarticular muscles[11,12]. Pain can also be a limiting factor in sports participation, as the joint may become unstable and wrist movements impaired, increasing the risk of injury[13]. Such events can exert a direct influence on the quality of life of athletes, as the wrist is an extremely important joint for functional and social activities, which can become limited due to injury and pain[13-15].

Considering the high rate of upper limb injuries, especially to the wrist and hand, and the fact that the high impact, repetitive strain, axial loading and rotational forces in cheerleaders result in a variety of injuries in these joints as well as nonspecific wrist pain, a study is needed to assess wrist muscle strength and activation, pain intensity and possible disability caused by pain. Therefore, the aim of the present investigation was to compare the wrist muscle strength, grip strength and electrical activity of the wrist flexors and extensors between cheerleaders with and without wrist pain as well as evaluate pain and upper limb function during the sport and activities of daily living. This study hypothesizes that cheerleaders with wrist pain have weaker flexor and extensor wrist muscles and impairment on electrical muscle activity compared with cheerleaders without wrist pain. Also, cheerleaders with wrist pain will report more pain and greater impairment in upper limb function during the sport and activities of daily living. Studies of this type can assist in the understanding of muscle function and pain as well as contribute to better evaluation, treatment and injury prevention protocols for the wrist and hand in cheerleaders to improve both performance in the sport and quality of life.

Methods

Study design

The present cross-sectional study was conducted at the author's institution. This study followed the STROBE statement[16]. Ethical approval was obtained from institutional review board of the institution (certificate number: 97742718.8.0000.5504). All participants signed a statement of informed consent. The data collection period was from February to December 2019.

Participants

The study was publicized on social media and during the of cheerleading teams in the city of São Carlos. Female and male cheerleaders in the national competitive modality aged 15 years or older were included in the study. The volunteers were divided into two groups: a control group (CG) composed of asymptomatic athletes (no wrist pain) and a symptomatic group (SG) composed of athletes with wrist pain regardless of the duration of the symptom. The exclusion criteria were amateur teams, hand or upper limb fracture and having undergone physical therapy treatment in the previous six months. The two groups were matched for sex and cheerleading position.

The participants were instructed not to perform any physical activity beyond habitual activity in the 48 hours prior to the tests. The wrist affected by pain was assessed in the SG. In cases of bilateral pain, the more symptomatic wrist was selected for evaluation and was determined by the pain level recorded on the Numerical Rating Scale[17]. The preferential upper limb was evaluated in the CG. It was used a convenience sample.

Outcome measures

Isokinetic assessment

An isokinetic dynamometer (Multi-Joint System 3, Biodex Medical System, New York, USA) was used for the isokinetic assessment of the wrist. This equipment is considered the gold standard for determining muscle strength and is a reliable method for measuring isometric and concentric strength of the wrist flexors and extensors[18,19]. Prior to the evaluation, the isokinetic dynamometer was calibrated and all procedures, including correction for the effect of gravity on the torque measurements, were performed following the instruction manual of the equipment[20].

The volunteer was positioned on the seat of the equipment with the chair inclined at 85° and was stabilized by straps over the trunk and pelvis. The forearm was supported and attached to a specific apparatus in pronation with the elbow flexed at 90° and the shoulder in the neutral position. The rotation axis of the dynamometer was aligned with the radiocarpal joint. The hand was positioned gripping the handle of the apparatus and the range of motion of the wrist was established beginning in the neutral position (0°)[20].

After calibration, the participant was familiarized with the activity by performing three submaximal and two maximum contractions[19]. The evaluations were performed in the isometric and concentric modes at a velocity of 45°/s, with five maximum repetitions of wrist flexion and extension, a 60-s rest interval between each isometric repetition and a three-minute rest period between tests[19]. The participants received verbal encouragement during the evaluation to stimulate a better performance throughout the procedure, but did not receive visual feedback from the equipment[21]. The order of the tests was randomized. Mean peak torque (PT) and total work (TW) of the wrist extensor and flexor in the isometric and concentric modes were considered for the purposes of analysis.

Test-retest reliability of the measures was determined prior to the trials. For such, 10 individuals (non-cheerleaders) without wrist pain were evaluated on two occasions separated by a maximum of seven days. The intraclass correlation coefficient and standard error of measurement were respectively 0.87 and 1.5 for isometric flexor torque and 0.9 and 0.4 for isometric extensor torque, demonstrating the excellent reliability of these measures.

Determination of grip strength

Grip strength was determined using a Lafayette handgrip dynamometer (Lafayette Hydraulic Hand Dynamometer TM - Model 5030K1 - Lafayette Instrument Company, Lafayette, IN). For the test, the guidelines of the American Society of Hand Therapists were adopted and participants performed three six-second trials, with a one-minute rest period between trials[22,23]. The mean of the three trials in kilogram-force (kgf) was used in the statistical analysis.

Assessment of electromyographic activity

Electrical activity of the wrist flexors and extensors was captured during the isokinetic and grip strength tests by surface electromyography (EMG), using the Trigno™ Wireless System (Delsys Inc., Boston, MA, USA) with a sampling frequency of 1200 Hz. Two surface electrodes (Trigno™ Wireless Sensor, Delsys Inc., Boston, MA, USA) were used, with a common rejection mode ratio greater than 80 dB. The EMG signals were digitized using a 16-bit A/D conversion board synchronized with the isokinetic dynamometer.

For the assessment of the wrist extensors, the electrode was positioned over the belly of the extensor carpi ulnaris (long and short) at a distance of 1/3 the length of the forearm closer to the elbow. The muscle was located by palpation during voluntary contraction with the forearm pronated[24]. A measure of general wrist extensor activity was considered due to the interference of the adjacent muscles and movement of the skin and therefore the movement of the electrodes in relation to the muscle[25]. For the assessment of the wrist flexors, electrodes were placed on the flexor carpi ulnaris (FCU) and flexor digitorum superficialis (FDS). To position the electrode over the FCU, the ventral region of the forearm was palpated at approximately ¼ the length of the forearm to the elbow near the ulna while the volunteer performed active wrist flexion.[26] For the FDS, the forearm was palpated ventrally at approximately ¾ of the distance from the elbow to the wrist while the participant flexed only the fingers[27]. Prior to the positioning of the electrodes, the skin at the attachment sites was prepared following the recommendations of Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM)[28]. The EMG variables considered in the statistical analysis were mean activation (MA) and the integral of the signal (IS).

Pain assessment

Pain intensity at rest and after a training session was evaluated using the 11-point Numerical Rating Scale, ranging from 0 (no pain) to 10 (worse pain possible). This is a valid, reliable scale for assessing pain intensity in adults[17].

Disabilities of the Arm, Shoulder and Hand (DASH)

The DASH questionnaire was developed to measure physical disability and symptoms of the upper limbs in a heterogeneous population and is composed of 30 items, each of which addresses performance on a functional task and is scores on a five-point Likert scale ranging from 1 (no difficulty or no symptom) to 5 (disability or extreme severity of symptoms that affect the performance on the task in question)[29]. DASH has two optional modules (each with four items) - one for sports and musical activities and one for work activities[29]. The version translated and validated for the Portuguese language was used in the present study[30].

Data processing

All muscle strength and activation data were processed using the Matlab software (Mathworks, USA). Three repetitions were considered for the analysis of the isokinetic dynamometer data, discarding the first and final repetitions. Mean PT and TW were considered for the analysis.

The EMG signals were initially filtered using a fourth-order, low-pass, zero-lag Butterworth filter from 20 to 400 Hz and were rectified and smoothed using a 65-ms moving root mean square (RMS) window[31]. The

EMG signal of each muscle was normalized by the activation peak during maximum isometric contraction. The peak of the RMS amplitude during maximum isometric contraction was considered 100% and MA during the repetitions was expressed as percentage of the peak. The integral of the EMG signal for each repetition was also calculated.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY, USA). The normality and homoscedasticity of the data were determined using the Shapiro-Wilk and Levene tests, respectively. Variables with non-normal distribution (total activation of EMG signal of finger flexors during the grip strength test and total work of concentric wrist extension) were transformed using inverse transformation. Fisher's exact test was used for the comparison of the categorical variables (experience, frequency and duration of training) between groups. The independent t-test was used to determine differences between groups regarding age, body mass index (BMI), sport modality and total DASH score. The Mann-Whitney U test was used for the comparison between groups regarding pain intensity at rest and after training. One-way multivariate analysis of variance (MANOVA) was conducted to determine the group effect (SG x CG) on variables related to strength and the EMG signals of peak torque and mean activation of the muscles during the strength tests (PT of flexion, MA of FCU, FDS and wrist extensors during isometric flexion; PT of flexion, MA of FCU and FDS muscles during concentric wrist flexion test; PT of wrist extension and MA of wrist extensors during isometric and concentric tests; TW of flexion, IS of FCU, FDS and wrist extensors during isometric flexion test; TW of flexion, IS of FCU and flexor digitorum superficialis during concentric wrist flexion test; TW of wrist extension and IS of wrist extensor during isometric and concentric tests) and grip strength with IS of the signal of the FDS, FCU and wrist extensors. The level of significance was set at 5% for all analyses ($\alpha = 0.05$).

Clinical relevance of the results of each variable in the comparison of the cheerleaders with and without wrist pain was determined based on the distribution method using the effect size (Cohen), minimal important difference (MID) and clinical judjment[32-36]. Cohen described effect sizes of 0.2, 0.5 and 0.8 as small, moderate and large, respectively[37]. However, an effect size ≥ 0.40 was considered clinically relevant, as reported in the study by Armijo-Olivo[36], since this value corresponds to a moderate effect that could be of interest to clinical practice. Thus, a result was considered clinically relevant if the effect size was moderate (≥ 0.40) and both MIDs were smaller than the mean difference between groups. A result was considered potentially clinically relevant if the effect size was moderate (0.5) or small to moderate (0.4-0.79) and only one of the MIDs was smaller than the mean difference between groups. A result was considered not clinically relevant if the effect size was small (0.20) and one of the MIDs was smaller than the mean difference between groups or if clinical judgment determined the result to be not clinically relevant[36].

Results

Thirty-three individuals were assessed for eligibility, and 11 were excluded based on the exclusion criteria. Of these, 22 participants (11 in the CG and 11 in the SG) matched the eligibility criteria. The characteristics of both groups can be seen in Table 1.

Table 2 displays data related to the isokinetic variables, grip strength and electrical muscle activity organized with the MANOVA grouping. Table 3 displays the pain and DASH scores of the two groups.

Mean differences and 95% confidence intervals between groups regarding the variables of interest and clinical relevance values are presented later.

Table 1 - Characteristics of participants.

Characteristics	Control Group (n = 11) Mean ± SD	Symptomatic Group (n = 11) Mean ± SD	p-value
Age (years)	22.4 ± 2.7	20.1 ± 2.1	0.09
BMI (kg/m^2)	22.9 ± 2.3	23.5 ± 4	0.64
Sex	n (%)	n (%)	-
Male	6 (54.5)	6 (54.5)	
Female	5 (45.4)	5 (45.4)	
Position			-
Base	9 (81.8)	9 (81.8)	
Flyer	2 (18.2)	2 (18.2)	
Experience			1.0
Up to one year	4 (36.4)	5 (45.5)	
More than one year	7 (63.6)	6 (54.5)	
Training frequency (days/week)			1.0
1-2	4 (36.4)	3 (27.2)	
3-4	4 (36.4)	4 (36.4)	
5-7	3 (27.2)	4 (36.4)	
Duration (hours of training			0.18
1 to 2 h	2 (18.2)	6 (54.5)	
More than 2 h	9 (81.8)	5 (45.5)	

*Statistically significant difference: $p \leq 0.05$.

Table 2 - Isometric and concentric torque of wrist flexor and extensor, grip strength and electrical muscle activity during muscle strength tests in cheerleaders with and without wrist pain.

		Control group (n = 11) Mean ± SD	Symptomatic group (n = 11) Mean ± SD	p-value
Isometric test	PT of wrist flexion (Nm)	10.6 ± 4.8	8.2 ± 3.2	0.2
	MA of flexor carpi ulnaris	47.2 ± 7.0	47.7 ± 9.1	0.9
	MA of flexor digitorum superficialis	49.6 ± 10.4	47.6 ± 9.1	0.6
	MA of wrist extensors	8.0 ± 4.6	11.4 ± 8.9	0.3
	PT of wrist extension (Nm)	4.9 ± 2.2	4.2 ± 2.0	0.5
	MA of wrist extensors	51.1 ± 5.9	50.2 ± 6.3	0.7
	TW of wrist flexion (J)	37.0 ± 17.6	30.0 ± 10.7	0.3
	IS of flexor carpi ulnaris (µV)	185.6 ± 27.6	187.5 ± 35.6	0.9
	IS of flexor digitorum superficialis (µV)	195.1 ± 41.0	187.3 ± 35.4	0.6
	IS of wrist extensors during flexion (µV)	31.6 ± 18.0	44.6 ± 34.8	0.3
	TW of wrist extension (J)	17.1 ± 7.9	14.6 ± 6.6	0.4
	IS of wrist extensors (µV)	201.1 ± 23.2	197.4 ± 24.9	0.7
Grip strength test	Grip strength	31.2 ± 10.9	29.1 ± 8.9	0.6
	IS of flexor carpi ulnaris (µV)	66.0 ± 59.0	74.0 ± 49.6	0.74
	IS of finger flexors (µV)	152.1 ± 264.2	116.1 ± 206.7	0.77
	IS of wrist extensors (µV)	87.5 ± 28.8	79.0 ± 33.5	0.53
Concentric test	PT of wrist flexion (Nm)	9.7 ± 5.0	6.7 ± 2.3	0.08
	MA of flexor carpi ulnaris	48.0 ± 18.5	30.7 ± 16.8	0.03[*]
	MA of flexor digitorum superficialis	57.0 ± 30.9	31.8 ± 10.8	0.02[*]
	PT of wrist extension (Nm)	5.3 ± 2.1	4.5 ± 1.4	0.3
	MA of wrist extensors	50.4 ± 23.9	34.4 ± 16.0	0.08
	TW of wrist flexion (J)	13.6 ± 9.8	8.6 ± 2.5	0.1
	IS of flexor carpi ulnaris (µV)	94.0 ± 35.9	63.0 ± 32.4	0.046[*]
	IS of flexor digitorum superficialis (µV)	121.5 ± 55.3	65.3 ± 19.7	0.005[*]
	TW of wrist extension (J)	13.5 ± 21.2	6.6 ± 2.3	0.05[*]
	IS of wrist extensors (µV)	106.8 ± 53.1	75.9 ± 42.0	0.15

[*]Statistically significant difference: $p \leq 0.05$.
Abbreviations: PT, peak torque; TW, total work; MA, mean activation; IS, integral of signal; Nm, Newton-meter; J, Joules; µV, microvolt.

Table 3 - Pain and DASH scores in cheerleaders with and without wrist pain.

Variables	Mean ± SD		Median (IQR)		p-value	Mann-Whitney U
	Control group (n = 11)	Symptomatic group (n = 11)	Control group (n = 11)	Symptomatic group (n = 11)		
Pain[a §]						
Resting	0	1.1 ± 1.3	0 (0)	0.5 (2.0)	0.006[*†]	27,500
Post-workout	0	5.9 ± 2.3	0 (0)	6.3 (2.5)	< 0.001[*†]	93,500
DASH scores						
Sports[b]	8.2 ± 6.4	16.3 ± 8.5	-	-	0.02[*]	-
Total[c]	14.8 ± 1.8	46.0 ± 16.8	-	-	< 0.001[*]	-

Abbreviations: DASH, Disabilities Arm, Shoulder and Hand; IQR, Interquartile Range; SD, standard deviation.
[a]Range of possible scores: 0 to 10; [b]Range of possible scores: 0 to 100; [c]Range of possible scores: 0 to 100; [§]Medians and interquartile ranges for pain classification; [†]p-values for Mann-Whitney U tests. [*]Statistically significant difference: $p \leq 0.05$.

Peak isometric torque of wrist flexion and extension and electrical activity of wrist flexors and extensors

No group effect was found regarding peak isometric wrist flexion torque or electrical muscle activity (Pillai's Trace = 0.15; F[4, 17] = 0.72; p = 0.59). However, a clinically relevant result was found for PT of wrist flexion (Table 4). Clinically relevant results were also found regarding activation of the FDS and FCU muscles (Table 5). A potentially clinically relevant result was found for MA of the wrist extensors (Table 5).

The MANOVA results revealed no group effect regarding peak isometric wrist extension torque or electrical muscle activity (Pillai's Trace = 0.03; F[2, 19] = 0.31; p = 0.74). However, a potentially clinically relevant result was found for PT (Table 5).

Isometric TW of wrist flexion and extension and electrical activity of wrist flexors and extensors

The MANOVA results revealed no group effect regarding isometric TW of wrist flexion or electrical muscle activity (Pillai's Trace = 0.12; F[4, 17] = 0.60; p = 0.67). A potentially clinically relevant result was found for total wrist flexion work (Table 4). The integral of the EMG signal of the FDS and FCU muscles was considered not clinically relevant. A potentially clinically relevant result was found for the IS of the wrist extensors (Table 5).

The MANOVA results revealed no group effect regarding isometric TW of wrist extension or electrical muscle activity (Pillai's Trace = 0.03; F[2, 19] = 0.32; p = 0.73). However, a potentially clinically relevant result was demonstrated for total wrist extension work (Table 4).

Grip strength and electrical activity of wrist flexors and extensors

The MANOVA results revealed no group effect regarding grip strength or electrical muscle activity (Pillai's Trace = 0.08; F[4, 17] = 0.35; p = 0.84). No clinical relevance was found for grip strength or activity of the wrist extensors during the test (Table 5).

Concentric PT of wrist flexion and extension and electrical activity of wrist flexors and extensors

The MANOVA results revealed group effect regarding concentric PT of wrist flexion or electrical muscle activity (Pillai's Trace = 0.45; F[3, 18] = 4.86; p = 0.01). Lower activation of the FCU (p = 0.03) and FDS (p = 0.02) was found in the SG compared to the CG. These differences were both statistically significant and clinically relevant (Table 5). No significant difference between groups was found regarding con-

Table 4 - Clinical relevance assessment of wrist flexor and extensor strength and hand grip strength in cheerleaders with wrist pain when compared with cheerleaders without wrist pain.

Outcome	Mean difference	Confidence interval for mean difference		Pooled SD	ES or standardized mean difference	ES based on SD of control group	Interpretation ES	MID (0.2) = 0.2 X pooled SD	MID (0.5) = 0.5 X pooled SD	Final decision clinical relevance
		Lower	Upper							
Isometric wrist strength										
PT flexor: CG vs. SG	2.4 N	-1.2	6.0	4.1	0.6	0.8	MES to LES	0.8	2.0	CR*
PT extensor: CG vs. SG	0.7 N	-1.2	2.6	2.1	0.3	0.4	SES to MES	0.4	1.1	PCR*
TW flexor: CG vs. SG	7 J	-6.1	20.1	14.8	0.5	0.6	MES	3.0	7.4	PCR*
TW extensor: CG vs. SG	2.5 J	-4.1	9.1	7.5	0.3	0.4	SES to MES	1.5	3.7	PCR*
Concentric wrist strength										
PT flexor: CG vs. SG	3.0 N	-0.5	6.5	3.9	0.8	1.3	LES	0.8	2.0	CR*
PT extensor: CG vs. SG	0.8 N	-0.8	2.4	1.8	0.4	0.5	MES	0.4	0.9	PCR*
TW flexor: CG vs. SG	5.0 J	-1.4	11.4	7.2	0.7	1.9	MES to LES	1.4	3.6	CR*
TW extensor: CG vs. SG	6.9 J	4.9	8.9	2.3	3.0	2.9	LES	0.5	1.2	CR*

(continued)

Table 4 - Continuation

Outcome	Mean difference	Confidence interval for mean difference		Pooled SD	ES or standardized mean difference	ES based on SD of control group	Interpretation ES	MID (0.2) = 0.2 X pooled SD	MID (0.5) = 0.5 X pooled SD	Final decision clinical relevance
		Lower	Upper							
Hand grip strength										
Maximal strength: CG vs. SG	2.1 kgf	-6.8	11	10.0	0.2	0.2	SES	2.0	5.0	NCR*

*Abbreviations: PT, peak torque; TW, total work; CG, control group; SG, symptomatic group; N, Newton; J, Joules; kgf, kilogram-force. Criteria for scoring: when both the effect size (ES) is ≥ 0.40 and the calculated minimal important difference (MIDs) are lower than the mean difference obtained between groups then, scored as clinically relevant (CR). If ES is small-moderate or moderate and only one of the MIDs is lower than the mean difference obtained between groups, it is scored potentially clinically relevant (PCR). If ES is small and one of the MID is accomplished, it is scored not clinically relevant (NCR). If both (ES and MID) are not accomplished or clinical judgement determines NCR, then it is scored NCR. Effect sizes are described according to Cohen, J: small effect size (SES): 0.20 (0-0.39); medium effect size (MES): 0.50 (0.4-0.79); large effect size (LES): ≥ 0.80.
[a]Based on Clinical Judgement.

Table 5 - EMG activity of the wrist flexor and extensor muscles during the strength tests in cheerleaders with wrist pain when compared with cheerleaders without wrist pain.

Outcome	Mean difference	Confidence interval for mean difference		Pooled SD	ES or standardized mean difference	ES based on SD of control group	Interpretation ES	MID (0.2) = 0.2 X pooled SD	MID (0.5) = 0.5 X pooled SD	Final decision clinical relevance
		Lower	Upper							
EMG activity (average activation) of the wrist flexor muscles during the peak isometric wrist flexor torque										
FCU: SG vs. CG	0.5	-7.0	8.0	8.4	0.1	0.1	SES	1.7	4.2	NCR[a]
FDS: CG vs. SG	2.0	-6.9	10.9	10.0	0.2	0.2	SES	2.0	5	NCR[a]
EXT: SG vs. CG	3.4	-3.1	9.9	7.3	0.5	0.7	MES	1.5	3.7	PCR[a]
EMG activity (average activation) of the wrist extensor muscles during the peak isometric wrist extensor torque										
EXT: CG vs. SG	0.9	-4.9	6.7	6.3	0.1	0.1	SES	1.3	3.1	NCR[a]
EMG activity (integral of the signal) of the wrist flexor muscles during the isometric wrist flexor total work										

(*continued*)

Table 5 - Continuation

Outcome	Mean difference	Confidence interval for mean difference		Pooled SD	ES or standardized mean difference	ES based on SD of control group	Interpretation ES	MID (0.2) = 0.2 X pooled SD	MID (0.5) = 0.5 X pooled SD	Final decision clinical relevance
		Lower	Upper							
FCU: SG vs. CG	1.9 μV	-27.4	31.2	33.0	0.1	0.1	SES	6.6	16.0	NCR[a]
FDS: CG vs. SG	7.8 μV	-27.1	42.7	39.2	0.2	0.2	SES	7.9	20.0	NCR[a]
EXT: SG vs. CG	13 μV	-12.7	38.7	28.9	0.5	0.7	MES	5.8	14.0	PCR[a]
EMG activity (integral of the signal) of the wrist extensor muscles during the isometric wrist extensor total work										
EXT: CG vs. SG	3.7 μV	-18.4	25.8	24.8	0.2	0.1	SES	5	12.0	NCR[a]
EMG activity (average activation) of the wrist flexor muscles during the peak concentric wrist flexor torque										
FCU: CG vs. SG	17.3	1.2	33.4	18.1	1.0	1.0	LES	3.6	9.1	CR[a]
FDS: CG vs. SG	25.2	4.5	45.9	23.2	1.1	2.2	LES	4.6	12.0	CR[a]
EMG activity (average activation) of the wrist extensor muscles during the peak concentric wrist extensor torque										
EXT: CG vs. SG	16.0	-2.4	34.4	20.7	0.8	1.0	LES	4.2	10.0	CR[a]
EMG activity (integral of the signal) of the wrist flexor muscles during the concentric wrist flexor total work										
IS FCU: CG vs. SG	31.0 μV	-0.2	62.2	35.1	0.9	0.9	LES	7.0	18.0	CR[a]
IS FDS: CG vs. SG	56.2 μV	17.3	95.1	43.8	1.3	2.8	LES	8.8	22.0	CR[a]
EMG activity (integral of the signal) of the wrist extensor muscles during the concentric wrist extensor total work										
EXT: CG vs. SG	30.9 μV	-14.1	75.9	50.5	0.6	0.7	MES	10.1	25.0	CR[a]
EMG activity of the wrist flexor and extensor muscles during hand grip strength test										
FCU: SG vs. CG	8 μV	-41.6	57.6	55.8	0.1	0.1	SES	11.2	28.0	NCR[a]

(*continued*)

Table 5 - Continuation

Outcome	Mean difference	Confidence interval for mean difference		Pooled SD	ES or standardized mean difference	ES based on SD of control group	Interpretation ES	MID (0.2) = 0.2 X pooled SD	MID (0.5) = 0.5 X pooled SD	Final decision clinical relevance
		Lower	Upper							
FDS: CG vs. SG	36 μV	-179.4	251.4	242.1	0.2	0.2	SES	48.4	121.0	NCR[a]
EXT: CG vs. SG	8.5 μV	-20.2	37.2	32.2	0.3	0.2	SES	6.4	16.0	NCR[a]

Abbreviations: CG, control group; SG, symptomatic group; μV, Microvolt; FCU, flexor carpi ulnaris; FDS, flexor digitorium superficialis; EXT, extensors. Criteria for scoring: when both the effect size (ES) is ≥ 0.40 and the calculated minimal important difference (MIDs) are lower than the mean difference obtained between groups then, scored as clinically relevant (CR). If ES is small-moderate or moderate only one of the MIDs is lower than the mean difference obtained between groups, it is scored potentially clinically relevant (PCR). If ES is small and one of the MID is accomplished, it is scored not clinically relevant (NCR). If both (ES and MID) are not accomplished or clinical judgement determines NCR, then it is scored NCR. Effect sizes are described according to Cohen, J: small effect size (SES): 0.20 (0-0.39); medium effect size (MES): 0.50 (0.4-0.79); large effect size (LES): ≥ 0.80.

[a]Based on Clinical Judgement.

centric peak wrist flexion torque ($p = 0.08$), but a clinically relevant result was demonstrated (Table 4).

The MANOVA results revealed no group effect regarding concentric PT of wrist extension or electrical muscle activity (Pillai's Trace = 0.23; $F[2, 19] = 2.85$; $p = 0.08$). However, a potentially clinically relevant result was demonstrated for PT (Table 4) and a clinically relevant result was found regarding MA of the wrist extensors (Table 5).

Concentric TW of wrist flexion and extension and electrical activity of wrist flexors and extensors

The MANOVA results revealed group effect regarding concentric TW of wrist flexion or electrical muscle activity (Pillai's Trace = 0.39; $F[3, 18] = 3.80$; $p = 0.03$). Lower activation of the FCU ($p = 0.046$) and FDS ($p = 0.005$) was found in the SG and these results were clinically relevant (Table 5). No significant difference was found between groups regarding concentric total wrist flexion work ($p = 0.1$), but a clinically relevant result was demonstrated (Table 4).

The MANOVA results revealed group effect regarding concentric TW of wrist extension or electrical muscle activity (Pillai's Trace = 0.36; $F[2, 19] = 5.34$; $p = 0.01$). Less total wrist extension work in the concentric mode was found in the SG ($p = 0.05$) and this result was clinically relevant (Table 4). The difference between groups regarding the IS during activation of the wrist extensors was non-significant ($p = 0.15$) but was considered clinically relevant (Table 5).

Pain and DASH

The SG had greater pain intensity at rest ($p = 0.006$) and after training ($p < 0.001$) compared to the CG (Table 3). These differences were both statistically significant and clinically relevant (Table 6). The SG also had higher sport modality ($p = 0.02$) and total DASH ($p < 0.001$) scores (Table 3). The result for the total DASH score was considered clinically relevant (Table 6).

Discussion

This is a pioneering study involving the analysis of muscle strength, electrical activity of the wrist flexors and extensors, pain and compromised upper limb function regarding performance in the sport and activities of daily living in cheerleaders with and without wrist pain. This study also explored issues related to the statistical significance and clinical relevance of the results.

Although statistical significance was not achieved for PT or TW in the isometric mode of wrist flexion and extension, the effect size and MID values indicated a clinically relevant difference in strength between

Table 6 - Pain level in rest and after training, and physical function on activities daily living and sports practice in cheerleaders with wrist pain when compared with cheerleaders without wrist pain.

Outcome	Mean difference	Confidence interval for mean difference		Pooled SD	ES or standardized mean difference	ES based on SD of control group	Interpretation ES	MID (0.2) = 0.2 X pooled SD	MID (0.5) = 0.5 X pooled SD	Final decision clinical relevance
		Lower	Upper							
Pain										
Rest: SG vs. CG	1.1	0.3	1.9	0.9	1.2	-†	LES	0.2	0.5	CR[a]
After training: SG vs. CG	5.9	4.5	7.4	1.6	3.6	-†	LES	0.3	0.8	CR[a]
Physical Function										
DASH Sport: SG vs. CG	8.1	1.4	14.8	7.5	1.1	1.3	LES	1.5	3.8	CR[a]
DASH General: SG vs. CG	31.2	16.3	46.1	16.8	1.9	1.9	LES	3.4	8.4	CR[a]

Abbreviations: CG, control group; SG, symptomatic group; DASH, Disabilities of the Arm, Shoulder and Hand.Criteria for scoring: when both the effect size (ES) is ≥ 0.40 and the calculated minimal important difference (MIDs) are lower than the mean difference obtained between groups then, scored as clinically relevant (CR). If ES is small-moderate or moderate only one of the MIDs is lower than the mean difference obtained between groups, it is scored potentially clinically relevant (PCR). If ES is small and one of the MID is accomplished, it is scored not clinically relevant (NCR). If both (ES and MID) are not accomplished or clinical judgement determines NCR, then it is scored NCR. Effect sizes are described according to Cohen, J: small effect size (SES): 0.20 (0-0.39); medium effect size (MES): 0.50 (0.4-0.79); large effect size (LES): ≥ 0.80. †The calculation could not be performed as the standard deviation is 0. [a]Based on Clinical Judgement.

cheerleaders with and without wrist pain. There is no difference between groups in wrist muscle strength in the isometric mode. However, a potentially clinically relevant result was found. Wrist extensors are important to the stabilization of the joint, especially during tasks that involve grip strength, as occurs in cheerleading. Thus, weakness of these muscles can exert an impact on the performance of the sport[38].

We also found no significant differences regarding EMG variables during the strength tests. However, the effect size and MID values indicated potentially clinically relevant differences between groups regarding MA and the IS of the wrist extensors during the assessment of PT and TW of wrist flexion, respectively. Cheerleaders with wrist pain had greater activation of the wrist extensors than those in the CG. This greater recruitment may be related to the strength deficit of the wrist flexors and may be a strategy for the stabilization of the joint during the isometric strength test, since the wrist extensors are responsible for stabilizing the joint[38-40].

No statistically significant or clinically relevant differences between groups were found regarding grip strength or electrical activity of the wrist flexors and extensors during the test. No previous studies were found evaluating wrist muscle strength and electrical activity in cheerleaders, thus, we were not able to compare our results. However, our grip strength results are compatible with data described by DiFiori et al.[41], who analyzed grip strength in gymnasts and found no difference between groups with and without with wrist pain. In contrast, Alizadehkhaiyat et al.[42] found the individuals with lateral epicondylalgia were 25% weaker than healthy individuals in this respect. Regarding electrical activity of the wrist muscles, one study found a change in the coordination of the wrist extensors and finger flexors during a gripping task in individuals with a diagnosis of lateral epicondylalgia compared to asymptomatic individuals[43]. This change in activation was characterized by greater contribution of the extensor digitorum communis and flexor digitorum profundus as well as lower contribution of the extensor carpi radialis brevis in relation to the total EMG activation of the muscles sampled.

Statistical significance was also not achieved regarding peak flexion or extension torque or TW of wrist flexion in the concentric mode. However, the effect size and MID values indicate a relevant difference in strength between cheerleaders with and without wrist pain under several conditions. Cheerleaders with wrist pain exhibited a tendency toward a reduction in muscle strength in the concentric mode, especially with regards to PT and TW of wrist flexion compared to cheerleaders without wrist pain. No previous studies were found evaluating concentric peak wrist torque in cheerleaders or gymnasts. Our results regarding peak wrist extension torque in the concentric mode are compatible with data described in a study conducted by Unyó et al.[44], in which individuals with lateral epicondylalgia did not exhibit significantly lower strength regarding concentric peak wrist extension torque. Concerning total wrist extension work in the concentric mode, cheerleaders with wrist pain had significantly lower values than those without wrist pain and this difference was clinically relevant.

Statistically significant and clinically relevant differences between groups were also found regarding MA and the IS of the FCU and FDS muscles during PT and TW in the concentric mode, respectively, as cheerleaders with wrist pain had lower electrical muscle activity.

Statistical significance was not achieved regarding MA or the IS of the wrist extensors during PT and TW of wrist extension in the concentric mode, respectively. However, the effect size and MID value indicate a clinically relevant difference in electrical activity, as cheerleaders with wrist pain had a tendency toward a reduction in electrical activity of the wrist extensors in the concentric mode compared to those without wrist pain.

Lastly, statistically significant and clinically relevant differences were found between groups regarding the level of pain at rest and after training as well as the sport module and total DASH scores, as cheerleaders with wrist pain had greater pain intensity and wrist impairment during the practice of cheerleading and activities of daily living. Thus, it seems that pain and compromised muscle function of the wrist and hand exert an impact on the movements of the sport as well as the performance of activities of daily living. Although no studies with the same population were found in the literature, DiFiori et al.[45] showed that wrist pain in adolescent gymnasts seems to have a negative impact on training, according to self-reports of the athletes.

As no normative values for PT and TW of wrist flexion and extension in the isometric and concentric modes have been determined for athletes and studies addressing wrist muscle strength are scarce, the presentation of statistical significance alone is insufficient for clinicians to know whether results are indeed important. Thus, clinical relevance needs to be assessed to determine whether results are useful. This aspect should be taken into consideration when evaluating and treating cheerleaders with wrist pain, as such individuals may have strength deficit in the wrist flexors and extensors and may benefit from the treatment of this deficiency.

The cross-sectional design of this study does not enable the establishment of cause-and-effect relationships between the variables analyzed. Thus, prospective studies are needed to follow up functional changes in the wrist muscles of cheerleaders. Studies addressing electromyographic activity during the performance of the movements of the sport should also be conducted to enable of better understanding of possible impairment. In addition, future studies with a larger sample size may compare the strength and activity of wrist muscles according to the sex of cheerleading athletes.

Even though this study was conducted with a small convenience sample, the findings provide valuable insights for both practice and future research. From a practical perspective, coaches and health professionals working with cheerleaders should consider implementing preventive training strategies focused on strengthening and balancing the wrist flexor and extensor muscles, as well as improving joint stability and endurance, to reduce the risk of wrist pain and overuse injuries. For future studies, it is recommended to employ longitudinal designs with larger and more representative samples to confirm these preliminary results and to evaluate the effectiveness of specific training and preventive protocols aimed at mitigating wrist injuries in cheerleaders.

Conclusion

In this study, cheerleaders with wrist pain have lower total wrist extension work in the concentric mode and higher MA and IS of the FCU and FDS muscle during concentric tests of wrist flexion. Despite the lack of a statistically significant difference, clinically relevant results were found regarding peak wrist flexion torque in both the isometric and concentric modes, total wrist flexion and extension work in the concentric mode as well as MA and the IS of the wrist extensors during concentric tests of wrist extension. Moreover, cheerleaders with wrist pain reported a higher level of pain at rest and following training sessions as well as greater wrist impairment during the practice of cheerleading and general upper limb impairment affecting the performance of activities of daily living, with both statistical significance and clinical relevance found for these variables.

It is important to emphasize that, due to the small sample size (n = 22), these findings should be interpreted with caution. The study had an exploratory nature, aiming to identify clinical trends rather than to infer epidemiological conclusions. Nonetheless, assessing clinical relevance remains important, as a result may not reach statistical significance but can still have meaningful implications for clinical practice. Based on the present findings, implementing preventive training programs focused on strengthening and balancing the wrist flexor and extensor muscles may be recommended to reduce pain and functional impairment among cheerleaders. These results may serve as a reference for future research and for guiding clinical reasoning in similar athletic populations.

AI use statement

No AI was used in this research.

Funding

São Paulo Research Foundation (FAPESP, grants #2017/20057-8, #2018/13122-0, and #2018/10329-3) and Coordination for the Improvement of Higher Education Personnel (CAPES, Finance Code 001).

Data availability statement

I declare, for all due purposes, that the research data is available in the body of the document.

Conflict of interest statement

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

Author contributions (CRediT)

Cristiano Carvalho: conceptualisation, investigation, methodology, data curation, writing - original draft, writing - review and editing. **Beatriz Cardinal Prando:** investigation, methodology, writing - original draft, writing - review and editing. **Marina Petrella:** data curation, formal analysis, writing - review and editing. **Giovanna Camparis Lessi:** data curation, formal analysis, writing - review and editing. **Paula Regina Mendes da Silva Serrão:** conceptualisation, methodology, visualization, supervision, writing - review and editing.

References

1. Shields BJ. Cheerleading-related injuries to children 5 to 18 years of age: United States, 1990-2002. Pediatrics. 2006;117(1):122-9. doi
2. Waters N. What goes up must come down! A primary care approach to preventing injuries amongst high-flying cheerleaders. Journal of the American Academy of Nurse Practitioners. 2013;25(2):55-64. doi
3. Brenner JS, Benjamin HJ, Cappetta CT, Demorest RA, Haltead ME, Kelly AKW, et al. Cheerleading injuries: epidemiology and recommendations for prevention. Pediatrics. 2012;130(5):966-71. doi
4. Hardy I, McFaull S, Saint-Vil D. Neck and spine injuries in Canadian cheerleaders: an increasing trend. Journal of Pediatric Surgery. 2015;50(5):790-2. doi
5. Carrier J, McKay D. Complete cheerleading. Champaign, Human Kinetics; 2005.
6. Shields BJ, Smith GA. Cheerleading-related injuries in the United States: a prospective surveillance study. Journal of Athletic Training. 2009;44(6):567-77. doi
7. Shields BJ, Smith GA. Epidemiology of strain/sprain injuries among cheerleaders in the United States. The Amer. J. of Emergency Medicine. 2011;29(9):1003-12. doi
8. Shields BJ, Smith GA. Epidemiology of cheerleading fall-related injuries in the United States. Journal of Athletic Training. 2009;44(6):578-85. doi
9. Marolde IB, Carvalho C, Serrão PRMS. Cheerleader injuries: a Brazilian cross-sectional study. Motriz: Revista de Educação Física. 2021;27:e1021002321. doi
10. Gaston RG, Loeffler BJ. Sports-specific injuries of the hand and wrist. Clinics in Sports Medicine. 2015;34(1):1-10. doi
11. Rutherford OM, Jones DA, Newham DJ. Clinical and experimental application of the percutaneous twitch superimposition technique for the study of human muscle activation. Journal of Neurology, Neurosurgery, and Psychiatry. 1986;49(11):1288-91. doi
12. McNair PJ, Marshall RN, Maguire K. Swelling of the knee joint: effects of exercise on quadriceps muscle strength. Archives of Physical Medicine and Rehabilitation. 1996;77(9):896-99. doi
13. Hong SJ, Lee MY, Lee BH. Effects of wrist stability training combined with grip strength exercise on pain and function in patients with nonspecific chronic wrist pain. Medicina (Lithuania). 2024;60(7):1144. doi
14. Aldanyowi SN, Aloraini LI. Personalizing injury management and recovery: a cross-sectional investigation of musculoskeletal injuries and quality of life in Athletes. Orthop Res Rev. 2024;16:137-51. doi
15. Bullock GS, Collins GS, Peirce N, Arden NK, Filbay SR. Playing sport injured is associated with osteoarthritis, joint pain and worse health-related quality of life: a cross-sectional study. BMC Musculoskelet Disord. 2020;21(1):111. doi
16. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. International Journal of Surgery. 2014;12(12):1495-9. doi
17. Karcioglu O, Topacoglu H, Dikme O, Dikme O. A systematic review of the pain scales in adults: which to use? The American Journal of Emergency Medicine. 2018;36(4):707-14. doi
18. Dvir Z. Isokinetics: muscle testing, interpretation and clinical applications. 2nd ed. Edinburgh, Churchill Livingstone; 2004.
19. Prando BC, Carvalho C, Petrella M, Serrão PRMS. Test-retest reliability of isometric and isokinetic wrist strength. J Orthop Sci. 2023;28(1):138-42. doi
20. Biodex Medical Systems. Biodex multi-joint system pro: setup/operation manual #850-000. Shirley, Biodex Medical Systems; 2000.
21. Hassan BS, Mockett S, Doherty M. Static postural sway, proprioception, and maximal voluntary quadriceps con-

traction in patients with knee osteoarthritis and normal control subjects. Ann Rheum Dis. 2001;60(6):612-8. doi

22. Fess EE. Grip strength. In: Clinical assessment recommendations. 2nd ed. Chicago, American Society of Hand Therapists; 1992. p. 41-5.
23. Figueiredo IM, Sampaio RF, Mancini MC, Silva FCM, Souza MAP. Test of grip strength using the Jamar dynamometer. Acta Fisiátrica. 2007;14(2):104-10. doi
24. Tossini NB, Lessi GC, Simões Zacharias AL, Corrêa e Silva GR, Seraphim Abrantes LS, Serrão PRMS. Impairment of electrical activation of wrist flexor and extensor muscles during gripping and functional activities in the early stage of hand osteoarthritis: a cross-sectional study. J Hand Ther. 2021;34(1):109-15. doi
25. Hansson GÅ, Balogh I, Ohlsson K, Granqvist L, Nordander C, Arvidsson I, et al. Physical workload in various types of work: part I. Wrist and forearm. Int. Journal of Industrial Ergonomics. 2009;39(1):221-33. doi
26. Salonikidis K, Amiridis IG, Oxyzoglou N, Giagazoglou P, Akrivopoulou G. Wrist flexors are steadier than extensors. International Journal of Sports Medicine. 2011;32(10):754-60. doi
27. Criswell E. Cram's. Introduction to surface electromyography. 2nd ed. Burlington, Jones and Bartlett Publishers, Inc; 2011.
28. SENIAM. SENIAM: European recommendations for surface electromyography. http://www.seniam.org [Accessed November 20, 2018].
29. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder, and head) [corrected]. The Upper Extremity Collaborative Group (UECG). Am J Ind Med. 1996;29(6):602-8. doi. Erratum in: Am J Ind Med 1996;30(3):372.
30. Orfale AG, Araújo PMP, Ferraz MB, Natour J. Translation into Brazilian Portuguese, cultural adaptation and evaluation of the reliability of the Disabilities of the Arm, Shoulder and Hand Questionnaire. Brazilian Journal of Medical and Biological Research. 2005;38(2):293-302. doi
31. Cook C, Burgess-Limerick R, Papalia S. The effect of upper extremity support on upper extremity posture and muscle activity during keyboard use. Applied Ergonomics. 2004;35(3):285-92. doi
32. Perera S, Mody SH, Woodman RC, Studenski SA. Meaningful change and responsiveness in common physical performance measures in older adults. Journal of the American Geriatrics Society. 2006;54(5):743-9. doi
33. Guyatt GH, Osoba D, Wu AW, Wyrwich KW, Norman GR. Methods to explain the clinical significance of health status measures. Mayo Clinic Proceedings. 2002;77(4):371-83. doi
34. Lemieux J, Beaton DE, Hogg-Johnson S, Bordeleau LJ, Goodwin PJ. Three methods for minimally important difference: no relationship was found with the net proportion of patients improving. Journal of Clinical Epidemiology. 2007;60(5):448-55. doi
35. Musselman KE. Clinical significance testing in rehabilitation research: what, why, and how? Physical Therapy Reviews. 2007;12(4):287-96. doi
36. Armijo-Olivo S, Warren S, Fuentes J, Magee DJ. Clinical relevance vs. statistical significance: using neck outcomes in patients with temporomandibular disorders as an example. Manual Therapy. 2011;16(6):563-72. doi
37. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale, Routledge Academic; 1988.
38. Forman DA, Forman GN, Robathan J, Holmes MWR. The influence of simultaneous handgrip and wrist force on forearm muscle activity. Journal of Electromyography and Kinesiology. 2019;45:53-60. doi
39. Holmes MWR, Tat J, Keir PJ. Neuromechanical control of the forearm muscles during gripping with sudden flexion and extension wrist perturbations. Computer Methods in Biomechanics and Biomedical Engineering. 2015;18(16):1826-34. doi
40. Levangie PK, Norkin CC. Joint structure and function: a comprehensive analysis. 5th rev ed. Philadelphia, F.A. Davis Company; 2011.
41. DiFiori JP, Puffer JC, Aish B, Dorey F. Wrist pain, distal radial physeal injury, and ulnar variance in young gymnasts: does a relationship exist? The American Journal of Sports Medicine. 2002;30(6):879-85. doi
42. Alizadehkhaiyat O, Fisher AC, Kemp GJ, Vishwanathan K, Frostick SP. Upper limb muscle imbalance in tennis elbow: a functional and electromyographic assessment. J. of Orthopaedic Research. 2007;25(12):1651-57. doi
43. Heales LJ, Vicenzino B, MacDonald DA, Hodges PW. Forearm muscle activity is modified bilaterally in unilateral lateral epicondylalgia: a case-control study. Scandinavian Journal of Medicine & Science in Sports. 2016;26(12):1382-90. doi
44. Unyó C, Chaler J, Rojas-Martínez M, Pujol E, Müller B, Garreta R, et al. A cross-sectional study comparing strength profile of dorsal and palmar flexor muscles of the wrist in epicondylitis and healthy men. European Journal of Physical and Rehabilitation Medicine. 2013;49(4):507-15.
45. DiFiori JP, Puffer JC, Aish B, Dorey F. Wrist pain in young gymnasts: frequency and effects upon training over 1 year. Clinical Journal of Sport Medicine. 2002;12(6):348-53. doi

Corresponding author

Cristiano Carvalho. Universidade Estadual da Paraíba, Departamento de Fisioterapia, 58429-500, Campina Grande, PB, Brazil.
E-mail: cristiano_ew@hotmail.com.

Manuscript received on December 12, 2024
Manuscript accepted on October 10, 2025