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original research

Elbow Joint Fatigue and Bench-Press Training

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Context: Bench-press exercises are among the most common form of training exercise for the upper extremity because they yield a notable improvement in both muscle strength and muscle endurance. The literature contains various investigations into the effects of different bench-press positions on the degree of muscle activation. However, the effects of fatigue on the muscular performance and kinetics of the elbow joint are not understood fully.

Objective: To investigate the effects of fatigue on the kinetics and myodynamic performance of the elbow joint in bench-press training.

Design: Controlled laboratory study.

Setting: Motion research laboratory.

Patients or Other Participants: A total of 18 physically healthy male students (age = 19.6 ± 0.8 years, height = 168.7 ± 5.5 cm, mass = 69.6 ± 8.6 kg) participated in the investigation. All participants were right-hand dominant, and none had a history of upper extremity injuries or disorders.

Intervention(s): Participants performed bench-press training until fatigued.

Main Outcome Measure(s): Maximal possible number of repetitions, cycle time, myodynamic decline rate, elbow-joint force, and elbow-joint moment.

Results: We observed a difference in cycle time in the initial (2.1 ± 0.42 seconds) and fatigue (2.58 ± 0.46 seconds) stages of the bench-press exercise ($P = .04$). As the participants fatigued, we observed an increase in the medial-lateral force ($P = .03$) and internal-external moment ($P \leq .04$) acting on the elbow joint. Moreover, a reduction in the elbow muscle strength was observed in the elbow extension-flexion ($P \leq .003$) and forearm supination-pronation ($P \leq .001$) conditions.

Conclusions: The results suggest that performing bench-press exercises to the point of fatigue increases elbow-joint loading and may further increase the risk of injury. Therefore, when clinicians design bench-press exercise regimens for general athletic training, muscle strengthening, or physical rehabilitation, they should control carefully the maximal number of repetitions.

Key Words: muscle strength, myodynamic decline rate, kinetics

Key Points

- The force and moment acting on the elbow joint increased under fatigue conditions.
- Elbow muscle strength was reduced after repeated bench-press cycles.
- Performing bench-press training to the point of fatigue increases the risk of injury to the elbow joint and upper extremity, so the maximal number of repetitions should be controlled carefully when clinicians design bench-press exercise regimens.

Bench-press exercises are convenient, easily learned, and readily adapted to various levels of difficulty, so they commonly are performed by health-conscious individuals and athletes to strengthen the upper extremity muscles.[1] When a person performs upper extremity movements, stability of the joints is ensured not only by the surrounding tissue (eg, ligaments and capsules) but also by muscular contraction strength. Therefore, maintaining and improving the muscular strength is essential in enhancing performance ability and preventing movement-related injuries.

Bench-press exercises are among the most common form of training exercise for the upper extremity because they yield notable improvements in both muscle strength and muscle endurance. The literature contains various investigations into the effects of different bench-press positions on the degree of muscle activation. For example, a narrow base position results in more electromyographic activity of the pectoralis major and triceps brachii muscle groups than a wide base position.[2] Investigators[3] also have studied the effect of push-up speed on the myodynamic and kinematic performance of the upper extremity muscle groups. However, the effects of fatigue on muscular performance and the kinetics of the elbow joint are not understood fully. Therefore, the purpose of our study was to investigate the effects of fatigue on the maximal possible number of repetitions, cycle time, myodynamic decline rate, elbow-joint force, and elbow-joint moment in repetitive bench-press training. We believe that the experimental results will provide useful information for formulating effective bench-press exercise strategies for athletic training and clinical rehabilitation purposes.

METHODS*

Participants

A total of 18 physically healthy male students (age = 19.6 ± 0.8 years, height = 168.7 ± 5.5 cm, mass = 69.6 ± 8.6 kg) participated in the investigation. They were right-hand dominant and had no history of upper extremity injuries or disorders. All participants provided written informed consent, and the study was approved by the Institutional Review Board of Kaohsiung Medical University.

Protocol

Before starting the bench-press exercise, participants were instructed to extend their elbows fully, and the width between the 2 hands was adjusted to a distance equal to 1.5 times the shoulder width. The *up state* was defined as the initial posture with the elbow in full extension. The *down state* was defined as the lowest barbell position when the bar was 1 fist away from the chest. Each bench-press cycle involved lowering a 19-kg barbell from the initial up state to the down state and then returning it to the up state. We instructed participants to repeat the cycle continuously until they were fatigued completely (ie, they were physically unable to perform any more repetitions). The aim of the experiment was to analyze the effects of fatigue on the kinematics and myodynamics of the elbow joint in both the initial and fatigue stages of the repetitive bench-press exercise. The *initial stage* was defined as the first 3 cycles of the experimental test, and the *fatigue stage* was defined as the last 3 cycles.

We evaluated the myodynamic performance of the elbow joint (ie, muscle strength) at 2 stages of the bench-press exercise (initial stage before bench press [ISBBP] and fatigue stage after bench press [FSABP]) by measuring the torque at the elbow joint using an isokinetic dynamometer (model KC125AF; Isokinetic International, East Ridge, TN). Torque measurements were obtained under 4 isometric test conditions: elbow extension, elbow flexion, forearm supination, and forearm pronation. For each participant and each isometric condition, the myodynamic decline rate of the bench press exercise was computed as the difference between ISBBP and FSABP divided by ISBBP, where ISBBP and FSABP were the measured torque values in the ISBBP and FSABP tests, respectively. The kinematics and kinetics of the elbow joint in the ISBBP and FSABP exercises were analyzed using an Expert Vision motion system (Motion Analysis Corporation, Santa Rosa, CA) that comprised 8 charge-coupled–device cameras operating at 240 frames per second and 1 force plate (model 9281B; Kistler Instrument Corp, Winterthur, Switzerland) sampling at a rate of 1000 Hz. Figure 1 shows the 11 reflective markers that were placed on selected anatomic landmarks on the right sides of the participants. The bilateral landmarks were selected in accordance with rigid body assumptions for the trunk (C7, T4, acromion process), arm (acromion process, medial epicondyles, lateral epicondyles), forearm (medial epicondyles, lateral epicondyles, radial styloid processes, ulnar styloid processes), and hand (radial styloid processes, ulnar styloid processes, third metacarpal bone). In performing the bench-press exercises, the distance and anatomic relationship between the midpoint of the 2 acromion markers and the actual lowest point of the chest over the sternum remained unchanged over each bench-press cycle. Therefore, in analyzing the kinematics of the upper extremity, the position of the chest was determined from an inspection of the acromion markers (ie, a specific marker was not placed on the chest). In addition, a triangular frame with 3 markers (upper, middle, and lower points) was placed on the arm to minimize potential measurement errors caused by skin movement of the epicondyles during the bench-press repetitions. Finally, the *center of the shoulder joint* was defined as the point 90% along a line starting from the center of the elbow joint (as calculated by the medial and lateral markers) and ending at the acromion marker.

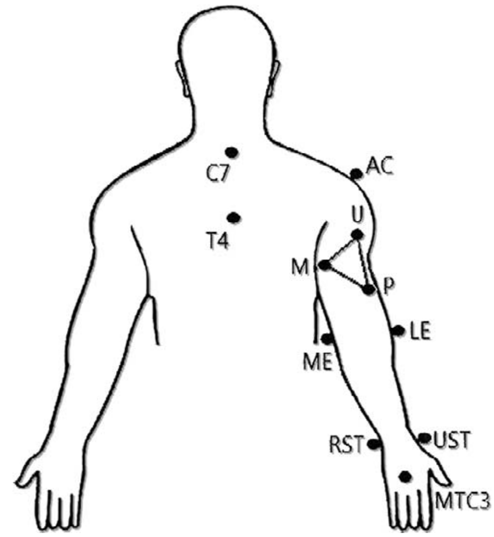

Figure 1. Placement of reflective markers on the bony anatomic landmarks. Abbreviations: C7, cervical vertebra 7; T4, thoracic vertebra 4; AC, acromion process; U, upper point; M, middle point; P, lower point; ME, medial epicondyle of the elbow; LE, lateral epicondyle of the elbow; RST, radial styloid process; UST, ulnar styloid process; and MTC3, third metacarpal bone. Reprinted with permission from Chou PPH, Hsu HH, Chen SK, Yang SK, Kuo CM, Chou YL. Effect of push-up speed on elbow joint loading. *J Med Biol Eng*. 2011;31(3):161–168.

Theorem and Governing Equations

We analyzed the force and moments acting on the upper extremity joints during the bench-press exercises using a 3-joint multilinkage system formed by the hand, forearm, arm, and trunk. The free-body diagrams of the hand, forearm, and arm are shown in Figure 2. The governing equations for the joint forces and joint moments are as follows:

From the free-body diagram of the hand,

$$\vec{F}_{hp} = m_h \vec{a}_h - m_h \vec{g} - \vec{F}_{hd}, \tag{1}$$

$$\vec{M}_{hp} = I_h \vec{a}_h - \vec{M}_{hd} - (\vec{r}_{hp} \times \vec{F}_{hp}) - (\vec{r}_{hd} \times \vec{F}_{hd}) + \vec{\omega}_h \times (I_h \cdot \vec{\omega}_h). \tag{2}$$

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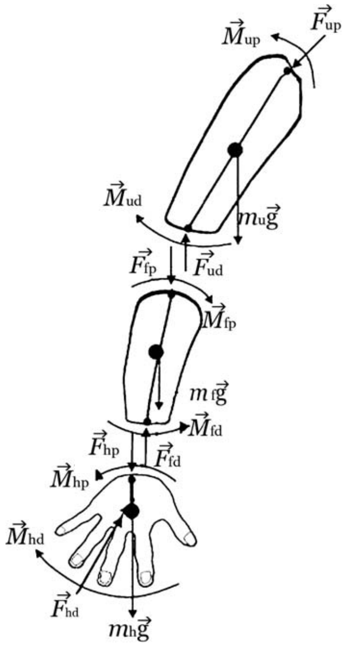

Figure 2. Segmental free-body diagram of the upper extremity. Abbreviations: $\vec{M}_{up}$, proximal arm joint moment; $\vec{F}_{up}$, proximal arm joint force; $\vec{M}_{ud}$, distal arm joint moment; $mu\vec{g}$, gravity force acting on the arm; $\vec{F}_{fp}$, proximal forearm joint force; $\vec{F}_{ud}$, distal arm joint force; $\vec{M}_{fp}$, proximal forearm joint moment; $mf\vec{g}$, gravity force acting on the forearm; $\vec{M}_{fd}$, distal forearm joint moment; $\vec{F}_{hp}$, proximal hand joint force; $\vec{F}_{fd}$, distal forearm joint force; $\vec{M}_{hp}$, proximal hand joint moment; $\vec{M}_{hd}$, distal hand joint moment; $\vec{F}_{hd}$, distal hand joint force; and $mh\vec{g}$, gravity force acting on the hand. Reprinted with permission from Chou PPH, Hsu HH, Chen SK, Yang SK, Kuo CM, Chou YL. Effect of push-up speed on elbow joint loading. *J Med Biol Eng*. 2011;31(3):161–168.

From the free-body diagram of the forearm,

$$\vec{F}_{fd} = -\vec{F}_{hp}, \tag{3}$$

$$\vec{M}_{fd} = -\vec{M}_{hp}, \tag{4}$$

$$\vec{F}_{fp} = m_f\vec{a}_f - m_f\vec{g} - \vec{F}_{fd}, \tag{5}$$

$$\begin{aligned}\vec{M}_{fp} = {} & I_f\vec{a}_f - \vec{M}_{fd} - (\vec{r}_{fp} \times \vec{F}_{fp}) - (\vec{r}_{fd} \times \vec{F}_{fd}) \\ & + \vec{\omega}_f \times (I_f \cdot \vec{\omega}_f),\end{aligned} \tag{6}$$

where $\vec{F}_{hp}$ is proximal hand joint force; $m_h\vec{a}_h$, effective force on the hand; $m_h\vec{g}$, gravity force acting on the hand; $\vec{F}_{hd}$, distal hand joint force; $\vec{M}_{hp}$, proximal hand joint moment; I_h, mass and moment of inertia of the hand; $\vec{a}_h$, angular acceleration of the hand; $\vec{M}_{hd}$, distal hand joint moment; $\vec{r}_{hp}$, rotation matrix describing relative rotation between local coordinates of proximal segment and global coordinates of the hand; $\vec{F}_{hp}$, proximal hand joint force; $\vec{r}_{hd}$, rotation matrix describing relative rotation between local coordinates of distal segment and global coordinates of the hand; $\vec{\omega}_h$, angular velocity of local segment of the hand; $\vec{F}_{fd}$, distal forearm joint force; $\vec{M}_{fd}$, distal forearm joint moment; $\vec{F}_{fp}$ is proximal forearm joint force; $m_f\vec{a}_f$, effective force on the forearm; $m_f\vec{g}$, gravity force acting on the forearm; $\vec{M}_{fp}$, proximal forearm joint moment; I_f, mass and moment of inertia of the forearm; $\vec{a}_f$, angular acceleration of the forearm; $\vec{r}_{fp}$, rotation matrix describing relative rotation between local coordinates of proximal segment and global coordinates of the forearm; $\vec{r}_{fd}$, rotation matrix describing relative rotation between local coordinates of distal segment and global coordinates of the forearm; and $\vec{\omega}_f$, angular velocity of the local segment of the forearm.

The kinematics and kinetics data of the elbow joint were obtained experimentally using the 3-dimensional motion analysis system. In performing the analysis using the multilinkage system described, we assigned the force and moment acting on a given joint opposite signs when substituted into the equilibrium equation for the proximal body segment. The segment mass and inertial data were estimated via anthropometry,[4] whereas the angular velocity and acceleration were calculated using the Euler parametric method.[5] The elbow-joint load then was calculated via an inverse dynamic procedure based on the Newton–Euler equations.

Data Reduction

The experimental data acquired by the Expert Vision motion system were smoothed via a generalized cross-validation spline-smoothing routine with a cutoff frequency of 6 Hz. The forces and moments acting on the elbow joint were calculated as functions of the temporal percentile during the bench-press cycle.

Statistical Analysis

We analyzed the number of bench-press repetitions, cycle time of each repetition, myodynamic performance during the ISBBP and FSABP, myodynamic decline rate, elbow-joint forces in the ISBBP and FSABP, and elbow joint moments in the ISBBP and FSABP using SPSS statistical software (version 12; SPSS Inc, Chicago, IL) via a paired *t* test with the α level set at .05.

RESULTS

Number of Bench-Press Repetitions and Cycle Time

The average number of repetitions before fatigue was 20.5 ± 4.55. We found a difference between the cycle times in the ISBBP (2.1 ± 0.42 seconds) and FSABP (2.58 ± 0.46 seconds) exercises ($P = .04$).

Myodynamic Performance in the ISBBP and FSABP

The myodynamic performance of the elbow and forearm in the ISBBP and FSABP exercises is shown in Table 1. We found a difference in the torque values obtained in the 2 stages of the bench-press exercise for each of the 4 isometric test conditions: elbow extension ($P = .003$), elbow flexion ($P = .001$), forearm supination ($P < .001$), and forearm pronation ($P < .001$). Moreover, a myodynamic decline rate of 46% was observed in the forearm-pronation condition.

Elbow-Joint Force in the ISBBP and FSABP

The peak value of the medial/lateral elbow joint force was higher in the FSABP than the ISBBP ($P = .03$), as illustrated in Table 2.

Table 1. Myodynamic Performance of Elbow-Joint and Forearm in the Initial and Fatigue Stages of Bench-Press Exercise (Mean ± SD)

Isometric Test Condition	Initial Stage Before Bench Press, N m	Fatigue Stage After Bench Press, N m	P[a]	Myodynamic Decline Rate of Bench Press, %[b]
Elbow joint				
Extension	37.63 ± 12.57	22.72 ± 8.72	.003[c]	39 ± 8.39
Flexion	55.86 ± 18.03	33.23 ± 10.49	.001[c]	39 ± 11.24
Forearm				
Supination	5.59 ± 1.20	3.26 ± 0.62	<.001[c]	40 ± 12.90
Pronation	7.91 ± 1.95	4.11 ± 1.31	<.001[c]	46 ± 12.96

[a] Paired *t* test.
[b] Myodynamic decline rate of bench press was calculated as the difference between the initial stage before bench press and fatigue stage after bench press divided by the initial stage before bench press.
[c] Indicates difference among 10 isometric tests ($P < .05$).

Elbow-Joint Moment in the ISBBP and FSABP

The up-state ($P = .004$), down-state ($P = .04$), and peak ($P = .03$) values of the supination-pronation elbow joint moment in the FSABP were higher than in the ISBBP (Table 3).

DISCUSSION

The experimental results show that fatigue affects the myodynamic and kinetic performance of the elbow joint. For example, the bench-press cycle time at the FSABP (2.58 ± 0.46 seconds) was longer than at the ISBBP (2.10 ± 0.42 seconds). Furthermore, the peak medial-lateral force acting on the elbow joint increased in the fatigue condition (Table 2). Thus, a large myodynamic decline rate was observed under all 4 isometric test conditions. The reduction in elbow muscle strength may affect the stability of the upper extremity, thereby increasing the risk of physical injury to the elbow joint or upper extremity.

The strength of the elbow flexor, elbow extensor, forearm supinator, and forearm pronator muscles decreased as the number of bench-press repetitions increased (Table 1). This finding is consistent with results presented in the literature for repetitive push-up exercises.[1,3,6] For example, Chou et al[1] reported that push-up exercises produce an increase in the activation of the triceps brachii, biceps brachii, and posterior deltoid muscle groups and, therefore, are beneficial in muscle strength training. Similarly, researchers have shown that, for push-up exercises performed to the point of fatigue, a myodynamic decline rate of more than 45% occurred in elbow-joint extension, flexion, abduction, and adduction isometric conditions.[3] The internal-external moments acting on the elbow joint were higher at the FSABP than at the ISBBP. Therefore, the risk of physical injury to the elbow joint and upper extremity was increased. Chou et al[6] noted that performing push-up exercises at a slower speed results in increased activation of the triceps brachii, biceps brachii, and posterior deltoid muscle groups. In our study, the bench-press cycle time increased in the FSABP, indicating a possible increase in the muscle activation of the upper extremity. Therefore, the risk of overloading the fatigued muscle groups was increased further.

The medial collateral ligament acts as a primary constraint on elbow motion and exerts a stabilizing effect on the elbow under valgus-varus stress.[7–10] O'Driscoll et al[11] found that an axial compression force to the elbow joint increased the valgus stress and, therefore, may result in posterolateral elbow dislocation or instability. Other researchers[12,13] have reported that the increased medial-lateral force acting on the elbow joint in forward falls increases the risk of physical injury. We observed that the peak medial-lateral (varus-valgus) force acting on the elbow joint increased in the FSABP training. Therefore, performing bench-press exercise beyond the point of fatigue should be monitored carefully to avoid elbow-joint overload and reduce the risk of elbow injuries.

Our study had limitations. Possible errors may derive from the equipment we used. Video motion-analysis system

Table 2. Elbow-Joint Force in the Initial and Fatigue Stages of Bench-Press Exercise (Mean ± SD)

Elbow-Joint Force	Initial Stage, % Body Weight	Fatigue Stage, % Body Weight	P[a]
Anterior(+)/posterior(−)			
Up	1.32 ± 0.37	1.58 ± 0.17	.95
Down	2.85 ± 0.83	2.62 ± 0.71	.79
Peak	2.93 ± 0.73	3.24 ± 1.07	.96
Medial(+)/lateral(−)			
Up	−1.64 ± 0.73	−1.92 ± 0.82	.66
Down	−4.12 ± 1.96	−4.91 ± 1.42	.40
Peak	−5.64 ± 1.56	−9.15 ± 1.75	.03[b,c]
Axial compression(+)			
Up	15.24 ± 1.46	15.76 ± 1.22	.05
Down	12.32 ± 1.85	12.74 ± 1.69	.33
Peak	16.2 ± 0.93	15.91 ± 1.80	.42

[a] Paired *t* test.
[b] Indicates difference ($P < .05$).
[c] Indicates fatigue stage > initial stage.

Table 3. Elbow-Joint Moment in the Initial and Fatigue Stages of Bench-Press Exercise (Mean ± SD)

Elbow-Joint Moment	Initial Stage, N m	Fatigue Stage, N m	P[a]
Varus(+)/valgus(−)			
Up	4.12 ± 0.98	3.93 ± 0.48	.97
Down	9.65 ± 1.92	9.86 ± 0.89	.99
Peak	9.78 ± 1.24	9.21 ± 1.53	.99
Flexion(+)/extension(−)			
Up	−6.61 ± 0.76	−6.82 ± 0.89	.90
Down	−9.23 ± 1.44	−9.94 ± 1.88	.94
Peak	−14.81 ± 1.46	−15.84 ± 1.75	.99
Supination(+)/pronation(−)			
Up	−1.67 ± 0.59	−3.09 ± 0.47	.004[b,c]
Down	1.70 ± 0.52	3.62 ± 1.19	.04[b,c]
Peak	3.44 ± 1.13	8.96 ± 1.46	.03[b,c]

[a] Paired *t* test.
[b] Indicates difference ($P < .05$).
[c] Indicates fatigue stage > initial stage.

errors can be referred to the joint center. When ball markers are used in motion analysis, 6- to 11-mm differences are typical. In addition, differences in anthropometric data for individual participants, including mass and inertia of segments, could result in 5% differences in moment and force calculations.

CONCLUSIONS

We investigated the effects of fatigue on the kinematics and myodynamic performance of the elbow joint in bench-press training. We found that the force and moment acting on the elbow joint increased under fatigue conditions. Moreover, elbow muscle strength was reduced after repeated bench-press cycles. The myodynamic decline rate in the forearm pronation condition was 46%. Reduced elbow muscle strength affects the stability of the upper extremity and, therefore, increases the risk of injury during the FSABP training.

Our results clarify the effects of fatigue on the kinetics and myodynamics of the elbow joint and provide a useful source of reference when formulating bench-press strategies for general athletic training and rehabilitation purposes. Importantly, our findings suggest that performing bench-press training to the point of fatigue increases the risk of injury to the elbow joint and upper extremity. Therefore, when designing bench-press exercise regimens, clinicians should control carefully the maximal number of repetitions.

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REFERENCES

1. Chou PH, Lou SZ, Chen SK, Chen HC, Hsu HH, Chou YL. Comparative analysis of elbow joint loading in push-up and bench-press. *Biomed Eng Appl Basis Commun*. 2011;23(1):21–28.
2. Cogley RM, Archambault TA, Fibeger JF, Koverman MM, Youdas JW, Hollman JH. Comparison of muscle activation using various hand positions during the push-up exercise. *J Strength Cond Res*. 2005;19(3):628–633.
3. Hsu HH, Chou YL, Huang YP, Huang MJ, Lou SZ, Chou PPH. Effect of push-up speed on upper extremity training until fatigue. *J Med Biol Eng*. 2011;31(4):289–293.
4. Dempster WT. *Space Requirements of the Seated Operator: Geometrical, Kinematic, and Mechanical Aspects of the Body, With Special Reference to the Limbs*. Wright-Patterson Air Force Base, OH: US Air Force; 1955. US Air Force Technical Report 55–159.
5. Haug EJ. *Computer-Aided Kinematics and Dynamics of Mechanical Systems: Basic Methods*. Vol 1. Boston, MA: Allyn and Bacon; 1989.
6. Chou PPH, Hsu HH, Chen SK, Yang SK, Kuo CM, Chou YL. Effect of push-up speed on elbow joint loading. *J Med Biol Eng*. 2011; 31(3):161–168.
7. Morrey BF, Tanaka S, An KN. Valgus stability of the elbow: a definition of primary and secondary constraints. *Clin Orthop Relat Res*. 1991;265:187–195.
8. Callaway GH, Field LD, Deng XH, et al. Biomechanical evaluation of the medial collateral ligament of the elbow. *J Bone Joint Surg Am*. 1997;79(8):1223–1231.
9. Regan WD, Korinek SL, Morrey BF, An KN. Biomechanical study of ligaments around the elbow joint. *Clin Orthop Relat Res*. 1991; 271:170–179.
10. Stewart OJ, Peat M, Yaworski GR. Influence of resistance, speed of movement, and forearm position on recruitment of the elbow flexors. *Am J Phys Med*. 1981;60(4):165–179.
11. O'Driscoll SW, Morrey BF, Korinek S, An KN. Elbow subluxation and dislocation: a spectrum of instability. *Clin Orthop Relat Res*. 1992;280:186–197.
12. Chou PH, Lou SZ, Chen HC, Chiu CF, Chou YL. Effect of various forearm axially rotated postures on elbow load and elbow flexion angle in one-armed arrest of a forward fall. *Clin Biomech (Bristol, Avon)*. 2009;24(8):632–636.
13. Chou PH, Huang YP, Lou SZ, Tseng WT, Wang RT, Chou YL. Effects of fatigue on stability of upper extremity during repetitive bench-press exercises. *J Med Biol Eng*. 2012;32(6):437–442.

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