Shoulder Rotator Torque and Wheelchair Dependence Differences of National Wheelchair Basketball Association Players

John Nyland, EdD, PT, Kevin Robinson, MS, PT, David Caborn, MD, Elizabeth Knapp, BS, Tony Brosky, PT, SCS.


Objective: Shoulder rotator muscle imbalances can contribute to subacromial impingement. The forces and movement patterns of wheelchair locomotion may contribute to these imbalances. This study attempted to determine whether National Wheelchair Basketball Association players of differing classifications had significant differences (p = .05) in concentric isokinetic peak shoulder rotator torque and torque ratios, and wheelchair locomotion dependence.

Design: Fifty-seven (class 1 = 12, class 2 = 24, class 3 = 21) of 117 total tournament participants (class 1 = 25, class 2 = 49, class 3 = 43) served as the convenience sample of volunteers for the survey portion, and 33 of these subjects (class 1 = 11, class 2 = 12, class 3 = 10) also entered the isokinetic portion of this study.

Setting: National wheelchair basketball tournament.

Results: Class 1 and 2 players had greater wheelchair dependence than class 3 players (p = .05). Peak torque or torque ratios generally did not differ among player classifications or with other populations. Class 1 players had weaker nondominant shoulder external rotator torque production at 60°/sec (p = .03) compared with other classes and at 180°/sec compared with class 3 players (p = .02), suggesting an inability to develop the "attenuation of dominance" noted among other groups. Diminished torque-producing capacity at 60°/sec related to greater wheelchair dependence among class 1 players (p = .054).

Conclusions: Class 1 players failed to demonstrate the acquired shoulder external rotator torque symmetry evident among class 2 and 3 players (with specific weakness of the nondominant shoulder external rotators). This torque symmetry difference was related to their greater dependence on wheelchair locomotion.

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ORGANIZED COMPETITIVE wheelchair athletics date back to 1948 and were developed originally as a means to rehabilitate disabled war veterans.1 Individuals with congenital deformities such as spina bifida, diseases such as polio, and traumatic injuries such as spinal cord injury or amputation are often active participants in wheelchair athletics. The number of disabled athletes participating in competitive sports has rapidly increased, and wheelchair sports have evolved from a rehabilitation process to competitions on local, state, national, and international levels.2-5 Competitive wheelchair athletes from 6 to 18 years of age form one of the fastest growing areas of wheelchair athletics.6 Increased and earlier participation in wheelchair athletics raises further concern over the prevention of sports-related injuries among this population.

THE BENEFITS OF WHEELCHAIR ATHLETICS

Disabled individuals who assume sedentary lifestyles often have diminished functional capacity, rehabilitation potential, and overall quality of life.1 A sedentary lifestyle can place the disabled individual at greater risk for the development of cardiovascular disease, adult-onset diabetes, and hypertension.7 Regular endurance activities for individuals who depend on a wheelchair as their primary method of locomotion may delay the progression of these diseases, reduce the incidence of respiratory infection, counter the development of osteoporosis, and decrease the risk of calculi formation.8 Increased habitual activity can also improve self-image9 and have a positive impact on other health behaviors such as smoking or alcohol consumption.10

SHOULDER INJURY OCCURRENCE

Dependence on a wheelchair for locomotion (wheeling) and repeated lifting of body weight during transfers place demands on the upper extremities of the disabled that exceed those of able-bodied persons.11,12 Wheelchair athletes rely on their upper extremities for both propulsion and weight bearing during daily living and sports activities.2 The integrity of the upper extremities is believed to be a major determinant regarding the ultimate level of functional independence of wheelchair athletes.2 With increased numbers of participants, and increased levels of competition, sports-related injuries among this population have also increased. In a 1972 survey conducted among American wheelchair athletes, 72% of respondents reported at least 1 injury as a result of sport participation, with soft tissue injuries such as sprains, strains, tendinitis, and bursitis being the most commonly reported.5 Hoeberigs and Verstappen12 reported that 42% of wheelchair basketball athletes developed upper extremity soreness during tournament play, with 34% reporting soreness in the deltoid region. Among National Wheelchair Athletic Association (NWAA) athletes, 61% of total injuries occur at the upper extremity, with 40% of these injuries occurring at the shoulder joint.14

Shoulder injury and pain are also common among wheelchair-dependent nonathletes.11,15,16 Bayley et al17 reported that 33% of wheelchair-dependent paraplegic persons had chronic,
persistent shoulder pain that was clinically diagnosed as subacromial impingement syndrome. Despite being recognized as a common and disabling problem, little has been written regarding the cause, prevention, or treatment of shoulder problems among wheelchair athletes.2

WHEELCHAIR ATHLETIC SUBACROMIAL IMPINGEMENT–MUSCULAR IMBALANCE RELATIONSHIP

The primary cause of overuse injury or pain involving the shoulders of wheelchair athletes is believed to be subacromial impingement.2 Overuse, lack of proper warm-up, glenohumeral and scapulo-thoracic dyskinesias (muscular imbalances), lack of dynamic lumbo-pelvic postural control, axial weight bearing forces, poor shoulder flexibility, repetitive overhead arm positioning, and fatigue may all contribute to subacromial impingement syndrome among wheelchair athletes.3,6,11,15-21

Exaggerated glenohumeral internal rotation and scapular protraction with downward rotation positioning is common for wheelchair athletes both at rest and during aggressive wheeling.3 Repetitive function with the shoulder girdle in this position reportedly promotes subacromial impingement in other athletic2,22 and nonathletic populations.23

When upper extremity weight bearing increases, as during wheelchair locomotion, changes in muscular agonist-antagonist torque-producing ratios similar to those noted after intensive conditioning programs may occur, often leading to greater torque production symmetry ("nondominance") between extremities and imbalances between opposing muscular groups.19,26 Shoulder muscle imbalances with humeral head depressor weakness (infraspinatus, teres minor, subscapularis, long head of biceps brachii) in combination with repetitive axial subacromial space loading from weight bearing may further exacerbate subacromial impingement among wheelchair athletes.2,16 Wheelchair propulsion selectively promotes the development of glenohumeral joint internal rotator (pectoralis major, teres major, latissimus dorsi, subscapularis) and scapular protractor (serratus anterior) torque-producing capacity, thereby creating muscular imbalances.

Dysfunctional sitting posture resulting from neurological deficits or simply poor habits can adversely affect the glenohumeral joint through changes in scapulo-thoracic articulation orientation. Subtle changes in glenoid fossa alignment can evoke compensatory muscular stabilization demands that eventually promote joint degeneration. Paraplegic persons with complete

Table 1: Subject Demographics

<table>
<thead>
<tr>
<th>NWBA Classification</th>
<th>Age (yrs)</th>
<th>Duration of Disability (yrs)</th>
<th>Wheelchair Basketball Playing Experience (yrs)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1 (n = 12)</td>
<td>35.7 ± 4</td>
<td>14.3 ± 5</td>
<td>11.0 ± 5</td>
<td>183 ± 10</td>
<td>80 ± 18</td>
</tr>
<tr>
<td>Class 2 (n = 24)</td>
<td>35.8 ± 6</td>
<td>17.8 ± 11</td>
<td>11.9 ± 6</td>
<td>180 ± 11</td>
<td>74 ± 15</td>
</tr>
<tr>
<td>Class 3 (n = 21)</td>
<td>34.4 ± 7</td>
<td>19.2 ± 11</td>
<td>11.8 ± 6</td>
<td>184 ± 10</td>
<td>88 ± 17</td>
</tr>
</tbody>
</table>

Characteristics presented as mean ± SD. p > .05.
spinal cord lesions below the second thoracic (T-2) spinal nerve root level can achieve partial sitting postural compensation for decreased erector spinae muscle group function by increased latissimus dorsi and upper trapezius muscle activation. When dynamic trunk control is compromised, these muscles may serve more as postural stabilizers for the trunk than as prime movers for the upper extremity, thereby further promoting glenohumeral muscular imbalances. The ability to dynamically control sitting posture is vital for proper scapulo-thoracic and glenohumeral function and efficient performance of functional tasks with the upper extremities. Spinal cord injured subjects tend to sit with their pelvis tilted 15° more posteriorly than normal subjects to enhance sitting balance in the absence of effective dynamic lumbo-pelvic control. This sitting posture further promotes inefficient scapulo-thoracic and glenohumeral positioning, motion, and torque-producing capacity.

NWBA RATING SYSTEM

According to a study performed in 1984, the National Wheelchair Basketball Association (NWBA) includes approximately 1,950 players on more than 165 men’s and women’s teams in 27 conferences. The NWBA is the oldest organization in the United States representing athletes with locomotor impairments. To be eligible for NWBA participation individuals must have permanent severe leg disability or paralysis of the lower portion of the body, as well as the potential for benefiting from participation in wheelchair basketball, and must be denied the opportunity to otherwise play basketball. The NWBA favors a functional classification system for its participants based on the quality and quantity of active muscle and the ability to perform specific tasks such as trunk rotation and picking a basketball up from the floor. This functional classification system generates three player categories, ranging from relatively higher spinal cord injured athletes (class 1), who are almost exclusively wheelchair dependent, to any of a wide variety of other medical conditions such as trunk rotation and picking a basketball up from the floor. Of these subjects, 33 (class 1 = 25, class 2 = 49, class 3 = 43) in the basketball population were asymptomatic for upper extremity or trunk pain participating in this portion of the study. Isokinetic testing was performed using a Cybex II isokinetic dynamometer and dual channel recorder and a Biodex Upper Extremity Chair. The NWBA classification was verified from tournament registration applications at the conclusion of the tournament.

Subjects

The study population was sampled from the 117 participants (class 1 = 25, class 2 = 49, class 3 = 43) in the basketball tournament. Fifty-seven (class 1 = 12, class 2 = 24, class 3 = 21) players volunteered to participate in the questionnaire portion of this study, which attempted to determine wheelchair dependence as the primary mode of transportation. The following question was used to determine wheelchair dependence: "Excluding motorized vehicles, I use a wheelchair as my primary method of transportation? percent of the time." Responses could range from "Never" to "All the Time." Before answering this question, subjects completed a trial question under the supervision of the principle investigator to become familiar with the visual analog scale (VAS) format and to increase measurement reliability. Additional information was obtained regarding the duration of disability, wheelchair basketball playing experience, height, and weight. Of these subjects, 33 (class 1 = 11, class 2 = 12, class 3 = 10) players volunteered to participate in the isokinetic portion of this study. Only subjects who were asymptomatic for upper extremity or trunk pain participated in this portion of the study. Isokinetic testing was performed using a Cybex II isokinetic dynamometer and dual channel recorder and a Biodex Upper Extremity Chair. The Biodex chair was used for its hydraulic lift capability, which enabled greater ease of transfer while simultaneously enabling replication of the test position described by Cahalan et al.

<table>
<thead>
<tr>
<th>NWBA Classification</th>
<th>Classification Ratio</th>
<th>Wheelchair Dependence (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1 (n = 12)</td>
<td>93.1 ± 15.0*</td>
<td></td>
</tr>
<tr>
<td>Class 2 (n = 24)</td>
<td>76.2 ± 35.4*</td>
<td></td>
</tr>
<tr>
<td>Class 3 (n = 21)</td>
<td>30.2 ± 30.6</td>
<td></td>
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</table>

Values presented as mean ± SD.
* Overall F = 26.7 (p = .0001); Class 1 and Class 2 > Class 3 (p = .05).

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<th>Wheelchair Dependence (mm)</th>
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<tbody>
<tr>
<td>Class 1 (n = 11)</td>
<td>45.8 ± 5.8</td>
<td>74.7 ± 11.7</td>
</tr>
<tr>
<td>Class 2 (n = 10)</td>
<td>42.2 ± 13.6</td>
<td>69.4 ± 14.9</td>
</tr>
<tr>
<td>Class 3 (n = 10)</td>
<td>41.4 ± 9.4</td>
<td>70.2 ± 13.3</td>
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</tbody>
</table>

Values presented as mean ± SD.

<table>
<thead>
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<th>NWBA Classification</th>
<th>Classification Ratio</th>
<th>Wheelchair Dependence (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1 (n = 11)</td>
<td>56 ± .08</td>
<td>36.9 ± 9.2</td>
</tr>
<tr>
<td>Class 2 (n = 10)</td>
<td>53 ± .11</td>
<td>31.3 ± 12.1</td>
</tr>
<tr>
<td>Class 3 (n = 10)</td>
<td>50 ± .10</td>
<td>31.2 ± 7.2</td>
</tr>
</tbody>
</table>

Values presented as mean ± SD.

<table>
<thead>
<tr>
<th>NWBA Classification</th>
<th>Classification Ratio</th>
<th>Wheelchair Dependence (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1 (n = 11)</td>
<td>.66 ± .11</td>
<td>.57 ± .06</td>
</tr>
<tr>
<td>Class 2 (n = 12)</td>
<td>.60 ± .13</td>
<td>.59 ± .11</td>
</tr>
<tr>
<td>Class 3 (n = 10)</td>
<td>.58 ± .08</td>
<td>.59 ± .12</td>
</tr>
</tbody>
</table>

Values presented as mean ± SD.
p > .05.
Class 3

randomly selected. Before determination of peak shoulder inter-

repeated for the opposite upper extremity. Following completion

submaximal practice repetitions. Following this, each subject

* NONDOM/DOM ER Peak Torque Ratio, 60°/sec, overall

Torso and forearm stabilization straps were used. Test position-

sured per manufacturer’s protocol.'

This procedure was performed initially at 60°/sec and then at

180°/sec. Standard recorder settings were used for damping,

chart speed, and torque scale.33 This procedure was then re-

peated for the opposite upper extremity. Following completion

of isokinetic testing, the upper extremity which was tested first was

Statistical Methods

Means and standard deviations were calculated for each vari-

able. Median and range values were also determined for the

wheelchair dependence variable. One-way analysis of variance

(ANOVA) tests were employed to determine whether significant

differences existed among the mean torque variables and wheel-

chair dependence values of each NWBA classification. When a

significant F value occurred, Tukey Honest Significant Differ-

ence post hoc comparisons were employed to specify how the

groups differed from each other. A probability level of

was chosen for all statistical procedures to demonstrate statisti-

cal significance.

RESULTS

Age, duration of disability, wheelchair sports experience,

height, and weight were not significantly different among player

classifications (table 1). Class 1 and 2 players depended on

wheelchairs as their primary mode of transportation to a greater

e xtent than class 3 players (p = .05) (table 2).

Comparisons of peak shoulder external or internal rotator
torque at 60°/sec and 180°/sec failed to reveal statistically

significant differences among player classifications (table 3). The

dominant upper extremity was defined as that which the subject

preferred to use while shooting a basketball. Comparisons of

dominant or nondominant peak shoulder external/internal rotar-
torque ratios at 60°/sec and 180°/sec failed to reveal significant

differences among player classifications (table 4).

Comparisons of nondominant/dominant peak shoulder exter-
nal and internal rotator torque ratios at 60°/sec and 180°/sec

found statistically significant decreases in external rotator torque

on the nondominant shoulder for class 1 players compared to

class 2 and 3 players at 60°/sec, and compared to class 3 players

at 180°/sec (table 5). Comparisons of nondominant/dominant

peak shoulder external rotator torque and NWBA player classi-

fication by wheelchair dependence found significant differences

at 60°/sec between class 1 players and other classes (table 6) (fig 3).

DISCUSSION

Comparisons were made among peak shoulder external and

internal rotator torque (table 3), dominant and nondominant

shoulder external/internal rotator peak torque ratios (table 4),

and nondominant/dominant shoulder external and internal rota-
tor peak torque ratios (table 5). Comparisons were also made

with other studies22,23,32,34-39 for peak shoulder external and inter-

nal rotator torque (table 7), dominant and nondominant shoulder

external/internal rotator peak torque ratios (table 8),22,23,32,34,39

and nondominant/dominant shoulder external and internal rota-
tor peak torque ratios (table 9).22,23,32,34,39 Studies were chosen

that used similar isokinetic testing procedures and positions

including shoulder positioning (although slight differences in

shoulder flexion and abduction angles did occur, and varying

isokinetic devices were used).

Peak shoulder rotator torques reported in this investigation

compared favorably with previous reports of wheelchair athletes

and other populations (table 7). Peak dominant and nondomi-
nant external/internal rotator torque ratios (table 4) also compared favorably with previous studies of wheelchair

athletes, and other populations (table 8).

Nondominant/dominant peak shoulder external rotator torque

results for class 1 wheelchair basketball players revealed statisti-
cal differences when compared to class 2 and 3 players (table 5)

and when compared to other athletic populations (table 9).

These results indicate that although class 1 wheelchair basket-

ball players fail to demonstrate significant differences in peak
torque capacity compared to class 2 or 3 players, they demon-

strate a lack of the acquired bilateral shoulder external rotator
torque symmetry (attenuation of dominance) reportedly com-

mon among other wheelchair athletes2,5,6 with weaker nondomi-
nant shoulder external rotators (table 8). Comparisons of

nondominant/dominant peak shoulder external rotation torque at

60°/sec and NWBA player classification by wheelchair depend-

cence provided further evidence of differences between class 1

players and other player classes (table 6) (fig 3).

Although not primarily assessed in this study, faulty sitting

posture may contribute more to the development of glenohu-

meral joint muscular imbalances among class 1 players more

than other wheelchair basketball players. Lesions at or above

Table 5: Nondominant (NONDOM)/Dominant (DOM) External Rotator (ER) and Internal Rotator (IR) Peak Torque Ratios

<table>
<thead>
<tr>
<th>NWBA Classification</th>
<th>NONDOM/DOM ER Peak Torque Ratio, 60°/sec</th>
<th>NONDOM/DOM IR Peak Torque Ratio, 60°/sec</th>
<th>NONDOM/DOM ER Peak Torque Ratio, 180°/sec</th>
<th>NONDOM/DOM IR Peak Torque Ratio, 180°/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1 (n = 11)</td>
<td>.77 ± .11*</td>
<td>.91 ± .14</td>
<td>.84 ± .14*</td>
<td>.93 ± .14</td>
</tr>
<tr>
<td>Class 2 (n = 12)</td>
<td>.97 ± .26</td>
<td>1.0 ± .16</td>
<td>1.04 ± .19*</td>
<td>1.04 ± .19*</td>
</tr>
<tr>
<td>Class 3 (n = 10)</td>
<td>1.0 ± .13</td>
<td>.98 ± .19</td>
<td>1.16 ± .30</td>
<td>1.0 ± .17</td>
</tr>
</tbody>
</table>

* NONDOM/DOM ER Peak Torque Ratio, 60°/sec, overall F = 4.8 (p = .01). Differences from Class 2 (p = .03), Class 3 (p = .02).

1 NONDOM/DOM ER Peak Torque Ratio, 180°/sec, overall F = 4.5 (p = .04). Differences from Class 2 (p = .11), Class 3 (p = .02).

Table 6: Class Comparisons of Wheelchair Dependence Versus Nondominant/Dominant External Rotator Torque Ratios at 60°/sec

<table>
<thead>
<tr>
<th>Source</th>
<th>Wheelchair Dependence</th>
<th>Sum-of-Squares</th>
<th>Degrees of Freedom</th>
<th>F Ratio</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1 External Rotator Ratio (n = 11)</td>
<td>95.6 ± 4.4</td>
<td>78.2</td>
<td>1</td>
<td>6.3</td>
<td>.034*</td>
</tr>
<tr>
<td>Class 2 External Rotator Ratio (n = 12)</td>
<td>68.9 ± 25.9</td>
<td>1953.4</td>
<td>1</td>
<td>3.6</td>
<td>.086</td>
</tr>
<tr>
<td>Class 3 External Rotator Ratio (n = 10)</td>
<td>23.9 ± 16</td>
<td>9.941</td>
<td>1</td>
<td>.035</td>
<td>.86</td>
</tr>
</tbody>
</table>

Wheelchair dependence values presented as mean ± SD.

* p ≤ .05.
the seventh thoracic (T-7) spinal nerve root level (class 1 by definition) can produce greater and more variable dynamic trunk control and shoulder mobility deficits than either of the other two player classifications. Concurrently, any loss of normal neural function above the T-7 spinal nerve root level may also affect both intrinsic and extrinsic shoulder girdle muscle torque producing capacity. When normal innervation is compromised, scapulo-thoracic and glenohumeral muscular imbalances may result, increasing susceptibility to subacromial impingement. Because of their greater wheelchair dependence, and potentially more impaired dynamic trunk control, class 1 wheelchair basketball players may be especially susceptible to subacromial impingement from glenohumeral joint muscular imbalances.

CONCLUSIONS

This study found that:
1. Differences did not exist among the concentric isokinetic peak shoulder rotator torque or nondominant/dominant torque ratios of differing NWBA player classifications or other populations;
2. Differences did exist in nondominant/dominant external rotator torque ratios, with class 1 wheelchair basketball players failing to demonstrate the symmetry of external rotator torque (attenuation of dominance) demonstrated by class 2 or 3 wheelchair basketball players or other populations, with specific weakness of the nondominant glenohumeral joint external rotators;
3. Class 1 wheelchair basketball players were more dependent on wheelchairs as their primary mode of transportation than either class 2 or 3 players, and this dependence related to differences in nondominant external rotator torque-producing capacity.

Athletic examinations and conditioning programs of wheelchair basketball players before participation should place particular emphasis on functionally evaluating the entire shoulder joint complex, with emphasis on glenohumeral external rotator and scapular retractor function as integrated members of a global kinetic chain that has an origin primarily from a sitting position. Class 1 players may be at greater risk for developing glenohumeral muscular imbalances than their class 2 or 3 counterparts because of greater wheelchair dependence, inherently
less trunk control, and a lack of acquired shoulder external rotator torque symmetry (as noted among class 2 and 3 players) with specific weakness of the nondominant glenohumeral external rotators. Further research is necessary with greater subject numbers while attempting to establish the clinical significance of these findings with functional capacity.

References

Supplier
a. Cybex Division of Lumex, Inc., 2100 Smithtown Avenue, Ronkonkoma, NY 11779.
b. Biodex Medical Systems, Inc., 20 Ramsay Road, Shirley, NY 11967-0702.