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The Effects of a 6-Week Dry Land Exercise Program for High School Swimmers

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Abstract

Background: In swimmers, the great number of stroke repetitions and force generated through the upper extremity, leaves the shoulder uniquely vulnerable to injury. Numerous high school swimmers experience shoulder pain, muscle shortening, and/or weakness leading to poor swim mechanics. **Purpose:** The purposes of this study were to examine the effects of a six week dry land intervention program on the 1) flexibility of the shoulder girdle, 2) muscular strength of the shoulder girdle and core, and 3) swim performance in high school aged competitive swimmers. **Methods:** 32 high-school swimmers were divided into control (N = 16) and intervention (N = 16) groups. Measurements for shoulder strength, core strength and swim times were measured. The intervention group completed a dry-land home exercise program three times a week for six weeks. **Results**: A MANOVA comparing flexibility, strength and swim times for pre- and post-test measurements by control and intervention group, revealed a significant group by time interaction. Post-hoc tests revealed a significant improvement in core strength in the intervention group ($F = 15.847$, $p = .000$). **Conclusion:** A 6-week dry land exercise program was effective in improving core strength, however, shoulder flexibility, strength and swim performance remained unchanged in this group.

Keywords: Swimmers, Shoulder Pain, High School, Strength, Exercise

1. Introduction

Swimmers are often classified as overhead athletes as they tend to suffer similar injuries. However, the sport of swimming is very different than other sports due to training in a prone position and use of both arms and legs for propulsion, with 90% of the propulsive force supplied by the upper extremities.

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(S. T. Aspenes & Karlsen, 2012; Fig, 2005; Heinlein & Cosgarea, 2010; E.E. Hibberd, Oyama, Spang, Prentice, & Myers, 2012; Kluemper, Uhl, & Hazelrigg, 2006; Troup, 1999) Another main difference is that land-based sports use the ground as a reference point of movement, while swimming does not involve ground contact. Therefore, swimmers must use their core as the reference point of movement, which reinforces the need for swimmers to have a strong core to be successful in the sport.(Fig, 2005) An estimated 5 million American high school-aged individuals participate in organized swimming each year.(Johnson, Gauvin, & Fredericson, 2003)Typically, swimmers begin their intense training at an early age of 8 to 11 years old,(Bak, 2010)with seasons typically occurring for 10 to 12 months of the year.(Beach, Whitney, & Dickoff-Hoffman, 1992)An average of 8 to10 arm cycles or strokes are performed by competitive swimmers per 25 m resulting in an estimated 25,000 to 30,000 rotations of the each shoulder per week.(Heinlein & Cosgarea, 2010; Johnson et al., 2003; Kluemper et al., 2006) Since this sport creates repetitive movements of the shoulder, it is at high risk for repetitive use injuries. This may be the reason 45-87% of swimmers complain that pain has limited their swim participation during their career resulting in either alteration or cessation of their normal swimming routines. (Bak, 2010; Beach et al., 1992; Folland & Archer, 2014; Elizabeth E Hibberd & Myers, 2013; E.E. Hibberd et al., 2012; King, 1995; Lynch, Thigpen, Mihalik, Prentice, & Padua, 2010; Van de Velde, De Mey, Maenhout, Calders, & Cools, 2011)

The high frequency and training of swimming can often lead to shoulder overuse injuries, or what Kennedy and Hawkin's originally described in 1978 as "swimmer's shoulder".(Blanch, 2004; Brushøj, Bak, Johannsen, & Faunø, 2007; Heinlein & Cosgarea, 2010; E.E. Hibberd et al., 2012)Research has reported that swimmers believe moderate shoulder pain is a normal part of swimming and that seventy-three percent of adolescent swimmers use pain medication to manage their shoulder pain.(Elizabeth E Hibberd & Myers, 2013)Some authors note the contributing factors in swimmer's shoulder are a swimmer's stroke technique, fatigue, practice habits (yardage, intensity, training methods) and physical characteristics of the athlete.(Gaunt & Maffulli, 2012; E.E. Hibberd et al., 2012; Swanik, Swanik, Lephart, & Huxel, 2002; Virag, Hibberd, Oyama, Padua, & Myers, 2014) Those unique characteristics of each athlete can be a combination of muscular strength imbalance, impaired muscular flexibility, joint laxity, altered scapular kinematics and poor posture.(Batalha, Raimundo, Tomas-Carus, Barbosa, & Silva, 2013; Kluemper et al., 2006; Lynch et al., 2010; Straub & Mattacola, 2004)

In the sport of swimming, the body is actually pulled over the arms of the swimmer, with the pectoralis major, latissimus dorsi and triceps brachii as the primary movers. Due to the dominance of the pectoralis major and latissimus dorsi, swimmers tend to have increased adduction and internal rotation strength. Factor this with the large amount of swim distances performed over the course of a year, an overdevelopment of anterior shoulder musculature may occur, thereby creating a strength imbalance with posterior shoulder musculature. Specifically, decreased lower trapezius and serratus anterior strength may account for impaired scapulohumeral rhythm. With increased fatigue and decreased force output, the inability to stabilize the scapula against the thoracic cage causes further scapular upward rotation.(Blanch, 2004) Literature also links an imbalance between the internal and external shoulder rotators and shoulder pain in swimmers.(Batalha et al., 2013; Straub & Mattacola, 2004)Weak scapular stabilizing muscles might cause a loss of proximal stability that would increase demands on the rotator cuff and perhaps contribute to faulty stroke mechanics, and ultimately, shoulder pain.(Russ, 1998; Tate et al., 2012)Numerous studies have reported that the internal rotator musculature is stronger in swimmers because of the repetitive concentric contractions required during the propulsive phase of the swim stroke. (Batalha et al., 2013; Beach et al., 1992; Straub & Mattacola, 2004; K. Swanik et al., 2002; K. A. Swanik et al., 2002) In contrast, external rotator strength is consistently weaker in swimmers and literature states that the high eccentric demands placed on the external rotator muscles cause chronic fatigue making it difficult to control glenohumeral-joint translation.(Straub & Mattacola, 2004; Weldon III & Richardson, 2001) As a swim season progresses, there is evidence that suggests an increase of muscular imbalances in the shoulder rotators of young swimmers, largely due to increased levels of internal rotator strength and endurance that are larger than those of the external rotators.(Batalha et al., 2013)

An increase in joint flexibility is desired in order for the swimmer to achieve greater range of motion during an arm stroke.(Troup, 1999) However, since the glenoid fossa is relatively shallow, excessive glenohumeral joint laxity can lead to future injury if the labrum, ligaments and muscles are not adequately stabilizing the joint.(Heinlein & Cosgarea, 2010) Therefore, a balance is necessary between upper extremity muscle strength and flexibility in hopes of reducing shoulder pain.(Troup, 1999)If a balance between the anterior and posterior musculature is not present, a tightness of the posterior capsule can result.

As a result the swimmer may present with decreased range of motion of the shoulder internal rotators and adductors as they have increased strength and are overdeveloped. (Blanch, 2004; E.E. Hibberd et al., 2012; Johnson et al., 2003)As the internal rotators and adductors are shortened, the shoulder external rotators and abductors tend to be overstretched and weak secondary to compensation.(E.E. Hibberd et al., 2012; Johnson et al., 2003) Blanch et al. notes that swimmers will attempt to compensate and alter their swimming mechanics secondary to the imbalance in shoulder range of motion.(Blanch, 2004) In order to decrease a swimmer's risk of swimmer's shoulder, an injury prevention program must address strength imbalances, impaired range of motion and flexibility.(E.E. Hibberd et al., 2012)Exercises aimed to strengthen the weak and lengthened muscles, while stretching the shortened shoulder muscles, have been reported to reduce the risk of shoulder impingement.(Lynch et al., 2010)Specifically, isolated stretches of the pectoralis minor, pectoralis major, posterior capsule and latissimus dorsi should be included in a dry land exercise program.(Blanch, 2004; Tate et al., 2012)In addition, scapular stabilizers, such as serratus anterior, lower trapezius and subscapularis muscles, external rotators and core musculature must be strengthened in order to have the endurance to cover the high yardage these athletes swim throughout their practices and competitions.(Batalha et al., 2013; Johnson et al., 2003)Currently, there is conflicting research on the effects of a dry land intervention program on glenohumeral muscle strength and swim performance.(S. Aspenes, Kjendlie, Hoff, & Helgerud, 2009; S. T. Aspenes & Karlsen, 2012; Sébastien Girold et al., 2012; S. Girold, Maurin, Dugué, Chatard, & Millet, 2007; Trappe & Pearson, 1994)

Therefore, the purposes of this study were to examine the effects of a six week dry land intervention program on the 1) flexibility of the shoulder girdle, 2) muscular strength of the shoulder girdle and core, and 4) swim performance in high school aged competitive swimmers.

2. Methods

2.1 Subjects and Recruitment

Thirty-two male and female swimmers between 14-17 years of age were recruited, on a volunteer basis, from local Fresno County high schools. The athletes were divided into a control group (N=16) and an intervention group (N=16) based on the high school they were enrolled.

The intervention group continued to participate in regularly scheduled swim practice as well as engaged in the six week dry land program. The control group was expected to continue to participate in their regularly scheduled swim practice without engaging in the six week dry land intervention program. Participants were excluded from the study if they had suffered a recent shoulder, cervical or thoracic injury for which they have sought medical attention and/orhad kept them from practicing. Testing was conducted poolside at the two local Fresno County high schools during normal practice hours. All participant's guardian read and signed a consent form approved by the university's institutional review board.

2.2 Testing and Instrumentation

During a scheduled swim practice, participants were screened in a random order atthe following testing stations. Participants had no warm up prior to measurements.

Station 1: Pectoralis Minor Muscle Length: Participants were placed in a supine position on the treatment the table. Their arms were placed on the side of body with their elbows flexed and rested against the lateral wall of the abdomen. The investigator measured the linear distance (cm) using a rigid standard plastic transparent right angle ruler. The base of the ruler was placed on treatment table and the vertical side was placed adjacent to lateral aspect of the acromion. Two measures were taken bilaterally, in succession. The average of the two measurements wasused for data analysis. Intra-rater reliability (0.96) was established prior to assessment of study participants. Lewis et al. demonstrated that the pectoralis minor muscle length test is reliable with an ICC of $\geq$ 0.90.(Lewis & Valentine, 2007)

Station 2: Posterior Shoulder Tightness: Participants were placed in a supine position on the treatment table. One investigator placed their hand underneath the scapula while the subject was asked to retract their scapula. The investigator stabilized the scapula in the retracted position. The participant's arm was passively horizontally adducted from a full horizontally abducted position. A second investigator recorded the amount of horizontal adduction that was obtained while the participant's scapula remained in the retracted position. The range was measured with the center of the goniometer place at the AC Joint, with one goniometer arm parallel to the ground and the other arm bisecting the humerus.

Both upper extremities were measured two times with the average of the two trials used for data analysis. Intra-rater reliability of 0.92 was established prior to assessment. Prior literature reported a reliability for intra-session at 0.91 and inter-rater at 0.94 for posterior shoulder tightness.(Myers et al., 2007)

Station 3: Upper Extremity Strength Measures: Strength of the bilateral shoulder internal and external rotators, lower trapezius, serratus anterior, and latissimus dorsiwas assessed using a hand held dynamometer (MicroFET3; Hoggan Industries, Draper, UT). Each participant performed two warm up trials and then two maximal testing trials of six seconds each. A third trial was performed if there was greater than a five pound difference between the first two trials. There was a 30 second rest break between each trial. The average of the two most similar trials was used for data analysis.

For this study, maximal isometric force production was tested for shoulder internal and external rotation with the participant in a prone position on a portable treatment table. The participant's tested arm was positioned at 90° abduction and 0° of rotation with the elbow flexed to 90°. This position has been recommended because swimmers are familiar with it and generates the highest torque values.(Malanga, Jenp, Growney, & An, 1996)Lower trapezius strength was measured with the participant lying prone and the arm over head at 145° of flexion with the thumb pointing to the ceiling. Latissimus Dorsi strength was also assessed with the participant prone with the testing arm next to the trunk in full extension. Serratus Anterior strength was measured with the participant supine and the shoulder and elbow flexed to 90°. Participants were asked to maximally retract scapula as investigator places the dynamometer on participant's elbow. The participant was asked to push forward on the dynamometer without rotating their body.

Station 4: Core Strength: Core strength was measured using the McGill Trunk Flexor Test. Participants were instructed to sit on the floor with knees and hips flexed to 90°. The participant's feet were stabilized by the investigator as upper body was placed against a support wedge with an angle of 60° from the floor. Participant's arms were folded across the chest with hands resting on shoulders. The participant was instructed to maintain the body position while the supporting wedge was pulled back 10 cm to begin the test. Time began once the wedge was pulled backward 10cm. Time ended once the participant could no longer maintain the correct position (Figure 3).

(Evans, Refshauge, & Adams, 2007; McGill, Childs, & Liebenson, 1999)Excellent reliability coefficients with the McGill Trunk Flexor test have been reported (0.97).(McGill et al., 1999)

Figure 1: McGill Trunk Flexor Test Position

Station 5: Swim Performance: After a standard warm-up, all participants performed a 50 m maximal test in freestyle stroke. The evaluation process was conducted in a 25 m outdoor pool, and the participants used in-water starts. Swim performance time was determined by an investigator with a stopwatch and was measured in seconds.

2.3 Intervention

The intervention group completed the dry-land intervention which consisted of two stretches and six strengthening exercises which addressed the shoulder stabilizers and core. The stretches targeted the posterior capsule and pectoralis muscles. The strengthening exercises targeted the shoulder external rotators, serratus anterior, lower trapezius and core musculature. A resistive band of medium was used for five out of the six strengthening exercises. The intervention was performed 3 days a week for 6 weeks before swimmers entered the pool for practice. The coaching staff supervised the intervention for a total of 15 minutes. Prior to beginning the program, the investigators instructed the coaching staff on the appropriate performance of exercises. Each week investigators supervised the swimmers perform the intervention to ensure appropriate performance and progression. Exercise progression included increasing the resistance of the band tensile strength.

Each participant received a handout which included a pictorial representation of each exercise as well as a description on instructions for execution (Appendix A). After the 6 week intervention was completed, each group (intervention group and control group) participated in post-testing.

3.0 Statistical Analysis

All of the results are presented with their mean and standard deviation (SD). A MANOVA was used to compare flexibility, strength and swim times for pre- and post-test measurements by control and intervention group. Univariate tests (ANOVAs) were subsequently used. SPSSv20 (SPSS Inc, Chicago, IL) was used for data analysis. A *p* value of less than or equal to 0.05 was considered statistically significant.

4.0 Results

Descriptive data about the participants can be seen in Table 1.

Variable	**Control (N=16)**			**Intervention (N=16)**		
	Mean	Min	Max	Mean	Min	Max
Age	15	14	16	15	14	17
Years Swimming	5.6	3	11	3.5	1	8
Hours swimming/wk	11.4	6	16	11.3	8	20
Dry-Land hours/wk	7.065	5	12	3.5	0	17
	Male	Female		Male	Female	
Gender	5	11		11	5	
	Right	Left		Right	Left	
Hand Dominance	16	0		14	2	

Table 1: Descriptive Data of Participants

A MANOVA comparing flexibility, strength and swim times for pre- and post-test measurements by control and intervention group, revealed a significant group by time interaction. Univariate tests (ANOVAs) exposed a significant group by time interaction for core strength. Subsequent post-hoc tests revealed a significant improvement in core strength in the intervention group.

4.1 Flexibility

No significant between-group differences were found for bilateral pectoralis minor length (p = .07 right; p = .08 left) or bilateral posterior capsule tightness (p = .22 right; p = .48 left) between pre and post test measures (Table 2).

		Control Group N= 16	Intervention Group N = 16
Pec Length (cm)			
Right	Pre	7.18 ± 0.82	7.19 ±1.33
	Post	7.37 ± 0.71	8.39 ± 1.34
Left	Pre	7.03 ±0.73	8.17 ± 1.49
	Post	6.77 ± 0.88	6.62 ± 1.45
Post Capsule (degrees)			
Right	Pre	109.81 ± 4.53	109.47 ± 3.98
	Post	110.21 ± 7.08	113.47 ± 8.62
Left	Pre	111.93 ± 7.63	109.47 ± 3.98
	Post	112.37 ± 7.19	109.78 ± 7.61

Table 2: Flexibility Results. Pec Length: Pectoralis Minor Length, cm: Centimeters, Post Capsule: Posterior Capsule

4.2 Strength

There was no significant differences were found between the control and intervention groups with respect to shoulder muscle strength. However, there was a significant between group difference on the measure of core strength within the intervention group ($F = 15.847$, $p = .000$) (Table 3).

		Control Group N= 16	Intervention Group N = 16
IR (lbs)			
Right	**Pre**	17.12 ± 4.05	14.45 ± 4.80
	Post	16.83 ± 4.31	14.89 ± 3.17
Left	**Pre**	18.24 ± 3.49	15.03 ± 4.66
	Post	17.85 ± 3.62	15.15 ± 3.71
ER (lbs)			
Right	**Pre**	16.39 ± 4.08	15.71 ± 5.77
	Post	16.52 ± 3.74	16.00 ± 4.68
Left	**Pre**	15.77 ± 2.77	14.68 ± 4.90
	Post	15.40 ± 2.23	14.43 ± 3.57
SA (lbs)			
Right	**Pre**	30.21 ± 6.73	26.16 ± 8.33
	Post	29.35 ± 6.87	25.31 ± 6.97
Left	**Pre**	29.06 ± 6.08	25.37 ± 9.63
	Post	28.39 ± 6.61	25.87 ± 6.06
LT (lbs)			
Right	**Pre**	7.22± 2.57	7.99 ± 3.80
	Post	7.69 ± 2.40	7.77 ± 2.79
Left	**Pre**	7.02 ± 1.86	8.06 ± 3.88
	Post	7.48 ± 1.91	8.05 ± 3.00
Lats (lbs)			
Right	**Pre**	11.55 ± 2.18	11.88 ± 3.76
	Post	11.68 ± 2.12	11.56 ± 3.14
Left	**Pre**	11.93 ± 1.97	11.88 ±3.68
	Post	12.01 ± 2.12	11.64 ± 3.53
Core (sec)			
	Pre	67.93 ± 25.81	88.60± 25.35
	Post	67.68 ± 22.83	118.44 ± 28.86*

Table 3: Strength Results. IR: Internal Rotators, ER: External Rotators, SA: Serratus Anterior, LT: Lower Trapezius, Lats: Latissimus Dorsi, lbs: Pounds, Sec: Seconds. * Significance @ $p \leq 0.05$.

4.3 Swim Performance

No statistical significance (p = .42) was found for the 50 m freestyle swim times in either the control or experimental groups (Table 4).

		Control Group N= 16	Intervention Group N = 16
Swim Performance (sec)			
	Pre	31.69± 2.61	31.52 ±3.48
	Post	31.74 ± 2.23	32.06 ± 3.08

Table 4: Swim Performance. Sec: Seconds

5.0 Discussion

The purposes of this study were to examine the effects of a six week dry land intervention program on the 1) flexibility of the shoulder girdle, 2) muscular strength of the shoulder girdle and core, and3) swim performance in high school aged competitive swimmers. We hypothesized that the intervention program would significantly improve shoulder girdle flexibility and strength, as well as core strength and swim performance. Results of this six week dry land intervention reveal that there wasa significant improvement in core strength with the swimmers in the intervention group as compared to the control group. Flexibility, muscular strength about the shoulder, and 50m freestyle swim times did not show improvements between the two groups. Referred to the "power center" of the body, the core musculature must be strong enough to stabilize a swimmer’s body in the water to maintain correct form. Core strength is a major component for swimmers that is commonly neglected. It not only helps stabilize the swimmer’s body in the water, it helps increase speed during flip turns and aids in propulsion through the water.

Research does indicate that core training can be accomplished while performing upper extremity shoulder exercises.(Brumitt & Dale, 2009; Keogh, Aickin, & Oldham, 2010; Tarnanen et al., 2008)Further, McMullen et al. stated that shoulder strength and core stabilization can be improved by utilizing a kinetic chain rehabilitation approach.(McMullen & Uhl, 2000)Both concepts for improving core strength were incorporated with the current study. Tarnanen et al. examined whether isometric upper extremity exercises could sufficiently activate core stabilizing muscles in 20 healthy adult women. (Tarnanen et al., 2008) The isometric exercises included shoulder extension, flexion, horizontal extension, horizontal flexion and bilateral shoulder extension. The authors concluded that external obliques and rectus abdominis muscles activated the most during bilateral shoulder extension and unilateral horizontal shoulder extension.(Tarnanen et al., 2008)Similarly, the current study incorporated a unilateral shoulder extension movement against a resistive band while performing the standing diagonal pull. Additionally, Brumitt et al. reported that the activation of core musculature during upper extremity exercise is positively influenced by movement speed.(Brumitt & Dale, 2009)Perhaps the movement speed while performing the upper extremity resistive band exercises in this current study aided in the significant improvements found with core strength.

Participants performed the upper extremity strengthening exercises for 30 seconds, rather than 10 or 12 repetitions commonly seen in strengthening programs. In addition, there is evidence to support the specificity principle and suggests that core stabilization training should be specific to the task performed.(Keogh et al., 2010)Keogh et al. examined core stability measures with an upper extremity exercise (shoulder press) and concluded that significant improvements in functional dynamic performance may be attained if the postures, mode and velocity of contraction performed in training are similar to the competitive tasks. In this present study, swimming speed was the functional dynamic performance. It is hypothesized that the plank progression exercises did not mimic the motion of a freestyle swim stroke enough to demonstrate improvements in swim times.

The stretching component of the intervention did not result in significant changes. In fact, the intervention group's mean pectoralis muscle lengthon the dominant side worsened at post-testing. Perhaps the unilateral stretch that was implemented in the present study was not as effective as the more traditional bilateral corner stretch which has been shown to be effective in swimmers. (Borstad & Ludewig, 2006) Furthermore, the lack of improvement of posterior capsule tightness may be attributed to the sole selection of the sleeper stretch. In contrast, McClure et al reported that the cross-body stretch is more effective than the sleeper stretch in improving internal-rotation range of motion deficits.(McClure et al., 2007) In future studies, the cross-body stretch should be added to the intervention program to provide additional stretching to the posterior capsule. While this study did not find improvements with swim performance after a dry land strengthening program, other authors have.(Sébastien Girold et al., 2012; S. Girold et al., 2007; Trappe & Pearson, 1994) While Trappe et al. reported a significant reduction in sprint swim times in 10 trained male collegiate swimmers, the weight-assisted intervention program was 12 weeks.

In contrast, this present study was 6 weeks in length and it is hypothesized that a 6 week period is too short to warrant significant swim time differences between the intervention and control group at post-testing. To strengthen the claim that 6 weeks is not long enough to detect a change in swim performance after a strengthening intervention, it has been reported that there are no improvements in swim times until 12 weeks.(S. Girold et al., 2007) In addition to the length of the present study, another plausible explanation for the lack of swim performance improvement could relate to the swim distance of 50 meters.

Aspenes et al. investigated the effect of a combined intervention of maximal strength training and high-intensity interval training on swim performance in 20participants ranging from 14 – 20 years of age.(S. Aspenes et al., 2009) Pre- and post-test measurements included measurements of the freestyle stroke for 50 m, 100 m and 400 m. The authors reported that the only significant difference noted between the intervention group and the control group was the improved swim time for the intervention group during the 400 m freestyle swim. Therefore, a longer swim distance may be necessary to determine if a dry land strength intervention is effective in improving swim performance. In disagreement with other research, this study did not find significant strength improvements of the shoulder internal and external rotators, serratus anterior, lower trapezius, or latissimus dorsi. (K. Swanik et al., 2002; Wang, McClure, Pratt, & Nobilini, 1999) One explanation for this is the selection of the five resistive band exercises. In contrast to prior research that has implemented the “Y”, “T” and “W” exercises for scapular stabilizing muscles, this study attempted to incorporate resistive exercises that also targeted core stabilizers, and thoracic extension and rotation.

The quadruped external rotation with trunk rotation (Appendix A) and diagonal pulls exercises were used to make the intervention program similar to movements needed in the water while swimming. In this current study, the exercise targeting the serratus anterior had the participant in either a hook-lying or supine 90-90 (hips and knees flexed to 90 degrees) and then perform a press-up against the resistance of the band. This position is in contrast to prior research which reports that the serratus anterior had the highest muscle activity during a weighted standard push-up plus position.(Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004) Further, all exercises in the intervention program were performed for 3 sets of 30 seconds. Again, this is in contrast to other interventions that performed 2 or 3 sets of 6-15 repetitions.(S. Aspenes et al., 2009; Garrido et al., 2010; Sébastien Girold et al., 2012)Another explanation for lack of strength gains could stem from the lack of consistent supervision during the dry land exercise intervention. While the coaches were verbally in agreement to supervise the participants prior to practice, the amount of direct supervision was questioned. Unfortunately due to scheduling, investigators were only able to attend 1 exercise session per week. The other 2 days had the coaches monitoring the dry land intervention. This lack of consistent supervision could certainly help explain why significant strength improvements were not detected.

6.0 Limitations

There were limitations in this study. Many participants were unable to return signed consent forms from their parents/guardians and this resulted in a limited sample population. Moreover, multiple participants did not complete the study due to various circumstances including injury, illness and vacation. Another limitation was the level of effort put forth by the participants in the intervention group. Although the coaches supervised the exercises, there was no specific way to monitor effort and correct form during each session.

7.0 Conclusion

A 6-week dry land exercise program was effective in improving core strength, however, shoulder flexibility, strength and swim performance remained unchanged in this group of participants. Further research is necessary to explore a dry land resistance program of a longer duration in anticipation of improving swim performance. Further, future research is needed to assess whether a dry land intervention program can reduce shoulder injuries prospectively.

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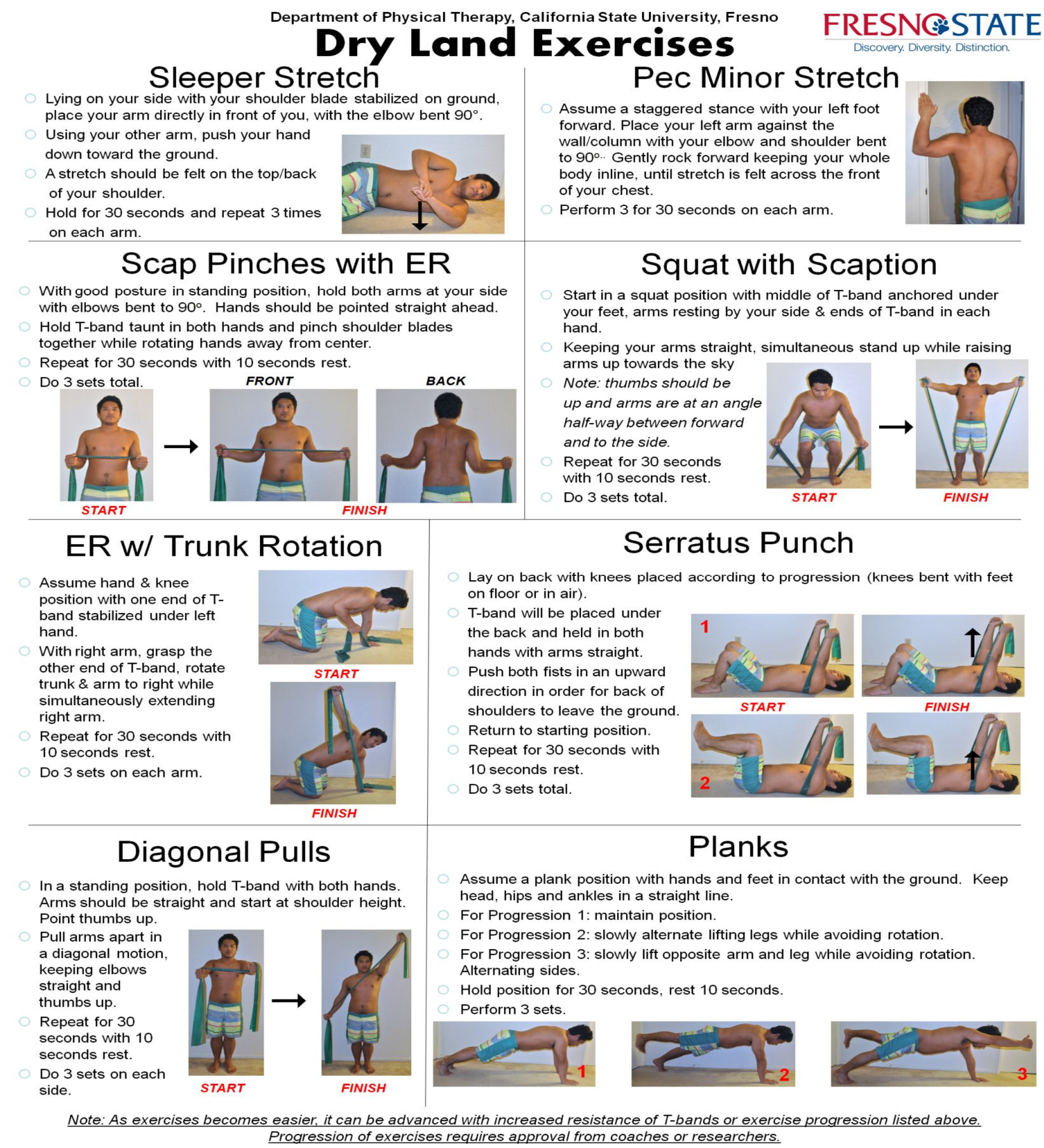
Appendix A



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Dry Land Exercises

Sleeper Stretch

- Lying on your side with your shoulder blade stabilized on ground, place your arm directly in front of you, with the elbow bent 90°.
- Using your other arm, push your hand down toward the ground.
- A stretch should be felt on the top/back of your shoulder.
- Hold for 30 seconds and repeat 3 times on each arm.

Pec Minor Stretch

- Assume a staggered stance with your left foot forward. Place your left arm against the wall/column with your elbow and shoulder bent to 90°. Gently rock forward keeping your whole body inline, until stretch is felt across the front of your chest.
- Perform 3 for 30 seconds on each arm.

Scap Pinches with ER

- With good posture in standing position, hold both arms at your side with elbows bent to 90°. Hands should be pointed straight ahead.
- Hold T-band taunt in both hands and pinch shoulder blades together while rotating hands away from center.
- Repeat for 30 seconds with 10 seconds rest.
- Do 3 sets total.

FRONT BACK

START FINISH

Squat with Scaption

- Start in a squat position with middle of T-band anchored under your feet, arms resting by your side & ends of T-band in each hand.
- Keeping your arms straight, simultaneous stand up while raising arms up towards the sky
- *Note: thumbs should be up and arms are at an angle half-way between forward and to the side.*
- Repeat for 30 seconds with 10 seconds rest.
- Do 3 sets total.

START FINISH

ER w/ Trunk Rotation

- Assume hand & knee position with one end of T-band stabilized under left hand.
- With right arm, grasp the other end of T-band, rotate trunk & arm to right while simultaneously extending right arm.
- Repeat for 30 seconds with 10 seconds rest.
- Do 3 sets on each arm.

START FINISH

Serratus Punch

- Lay on back with knees placed according to progression (knees bent with feet on floor or in air).
- T-band will be placed under the back and held in both hands with arms straight.
- Push both fists in an upward direction in order for back of shoulders to leave the ground.
- Return to starting position.
- Repeat for 30 seconds with 10 seconds rest.
- Do 3 sets total.

1 START FINISH 2

Diagonal Pulls

- In a standing position, hold T-band with both hands. Arms should be straight and start at shoulder height. Point thumbs up.
- Pull arms apart in a diagonal motion, keeping elbows straight and thumbs up.
- Repeat for 30 seconds with 10 seconds rest.
- Do 3 sets on each side.

START FINISH

Planks

- Assume a plank position with hands and feet in contact with the ground. Keep head, hips and ankles in a straight line.
- For Progression 1: maintain position.
- For Progression 2: slowly alternate lifting legs while avoiding rotation.
- For Progression 3: slowly lift opposite arm and leg while avoiding rotation. Alternating sides.
- Hold position for 30 seconds, rest 10 seconds.
- Perform 3 sets.

1 2 3

Note: As exercises becomes easier, it can be advanced with increased resistance of T-bands or exercise progression listed above. Progression of exercises requires approval from coaches or researchers.