Hip muscle imbalance and low back pain in athletes: influence of core strengthening

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ABSTRACT

NADLER, S. F., G. A. MALANGA, L. A. BARTOLI, J. H. FEINBERG, M. PRYBICIEN, and M. DEPRINCE. Hip muscle imbalance and low back pain in athletes: influence of core strengthening. *Med. Sci. Sports Exerc.*, Vol. 34, No. 1, 2002, pp. 9–16. **Purpose:** The influence of a core-strengthening program on low back pain (LBP) occurrence and hip strength differences were studied in NCAA Division I collegiate athletes. **Methods:** In 1998, 1999, and 2000, hip strength was measured during preparticipation physical examinations and occurrence of LBP was monitored throughout the year. Following the 1999–2000 preparticipation physicals, all athletes began participation in a structured core-strengthening program, which emphasized abdominal, paraspinal, and hip extensor strengthening. Incidence of LBP and the relationship with hip muscle imbalance were compared between consecutive academic years. **Results:** After incorporation of core strengthening, there was no statistically significant change in LBP occurrence. Side-to-side extensor strength between athletes participating in both the 1998–1999 and 1999–2000 physicals were no different. After core strengthening, the right hip extensor was, on average, stronger than that of the left hip extensor ($P = 0.0001$). More specific gender differences were noted after core strengthening. Using logistic regression, female athletes with weaker left hip abductors had a more significant probability of requiring treatment for LBP ($P = 0.009$) **Conclusion:** The impact of core strengthening on collegiate athletes has not been previously examined. These results indicated no significant advantage of core strengthening in reducing LBP occurrence, though this may be more a reflection of the small numbers of subjects who actually required treatment. The core program, however, seems to have had a role in modifying hip extensor strength balance. The association between hip strength and future LBP occurrence, observed only in females, may indicate the need for more gender-specific core programs. The need for a larger scale study to examine the impact of core strengthening in collegiate athletes is demonstrated. **Key Words:** DYNAMOMETER, GENDER, GLUTEUS MAXIMUS, GLUTEUS MEDIUS

Low back pain (LBP) in an athletic population is not uncommon, and its occurrence has been well documented in various sports including football, golf, gymnastics, running, soccer, tennis, and volleyball (4,6,16,26,29,30). Nadler et al. noted that athletes with lower extremity overuse or acquired ligamentous injuries were significantly more likely to require treatment for LBP during the ensuing year (26). Various other factors have been reported to be associated with LBP, including poor muscle endurance, altered muscle firing rates, muscular imbalance, inflexibility of the lower extremities, and leg length discrepancies (3,9,26). Nadler et al. demonstrated no association between muscle inflexibility or leg length discrepancy and the development of LBP (26).

With regard to muscular influences on LBP, the hip musculature plays a significant role in transferring forces from the lower extremity up toward the spine during upright activities and thus theoretically may influence the development of LBP (17,23). Poor endurance and delayed firing of the hip extensor (gluteus maximus) and abductor (gluteus medius) muscles have previously been noted in individuals with lower extremity instability or LBP (1,5,8,14,18). Beckman and Buchanan noted a significant delay in latency of the gluteus medius muscle in those with chronic ankle instability as compared with normal controls (1). DeVita et al. noted an alteration in firing of the proximal hip musculature in those with anterior cruciate insufficiency (8). Jaramillo et al. demonstrated significant strength deficits of the ipsilateral gluteus medius in patients who had undergone knee surgery (14). Kankaanpaa et al. and Leinonen et al. demonstrated poor endurance of the gluteus maximus in those with chronic LBP (18,22).

Gender-specific strength differences in LBP occurrence have also been noted. Nadler et al. demonstrated a significant asymmetry in hip extensor strength in female athletes with reported LBP in the previous year. Specifically, female athletes with reported LBP in the past year were observed to have significantly weaker right as compared with left hip extensors (27). In a follow-up study, female athletes previously determined to have weaker right extensors had an increased probability of developing LBP. Female athletes with significantly stronger right extensors, however, had the lowest probability of developing LBP over the ensuing year. No relationship between hip strength and LBP was noted in

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TABLE 1. Timeline of data collection in relation to the incorporation of core strengthening.

Dates	Data Collected
July–August 1998	Hip strength data 1998–1999 collected (abductors and extensors)
September 1998–May 1999	Generated list of athletes requiring treatment for LBP
July 1999–August 1999	Hip strength data 1999–2000 collected (abductors and extensors)
August 1999–September 1999	Core-strengthening program begins
September 1999–May 2000	Generated list of athletes requiring treatment for LBP
July–August 2000	Hip strength data 2000–2001 collected (extensors only)

male athletes (28). McGill et al. noted similar differences between males and females with regard to the muscular endurance of the trunk flexors, extensors, and lateral flexors (24).

Core strengthening has come into prominence in sports training as a method to condition athletes with the hope of preventing injury to the spine and/or extremities. The main emphasis of core strengthening is focused on muscular stabilization of the abdominal, paraspinal, and gluteal muscles to provide better stability and control for sporting activity. Past studies have shown the importance of pelvic stabilization in training the lumbar extensor muscles. Pollock et al. showed that resistance exercise training with pelvic stabilization improved development of lumbar extension strength (33). Jeng et al. reported that the occurrence of LBP may be decreased by strengthening the back, legs, and abdomen to improve muscular stabilization (15). To our knowledge, no study has evaluated the impact of a core-strengthening program on the incidence of LBP or its influence on strength balance of the proximal hip musculature. This present study was undertaken to evaluate these effects in light of the perceived yet untested benefits of core strengthening.

METHODS

The study population included different groups of NCAA Division I college athletes from two consecutive academic years (1998–1999 and 1999–2000). Additionally, hip extensor strength data were evaluated from the 2000–2001 preparticipation physical examination. Table 1 shows a timeline of data collection in relation to the incorporation of core strengthening. Institutional review board (IRB) approval was obtained to acquire and analyze hip muscle strength data. Immediately after routine musculoskeletal and cardiovascular evaluations, athletes performed a strength test of their hip extensor (gluteus maximus) and abductor (gluteus medius) muscles. Athletes were then tracked during the following year, with any athlete requiring treatment for LBP, unrelated to blunt trauma to the region, recorded by the athletic trainer. Data were maintained in the athletic training office. At this time, 1998–1999 and 1999–2000 data have been obtained. Athletes requiring LBP treatment in the 2000–2001 academic year will be obtained at the end of this academic year. All preparticipation physicals

FIGURE 1—Measurement of the left hip abductor.

and treatment for LBP were performed within the college athletic training department.

A commercially available dynamometer (Chatillon, Lexington, KY) incorporated into a specially designed anchoring station was utilized for hip strength testing. This device has been previously determined to have high reliability (ICC = 0.94–0.98) (25). The dynamometer anchoring station was stabilized to a table, and before each test, was adjusted according to the subject's size. For the hip extensor (gluteus maximus), it was positioned 1–1.5 inches above the midthigh region. For the hip abductors, it was placed 4 inches above the lateral aspect of the distal thigh. The sequence and side of the gluteus medius and maximus strength measurements were randomized for each subject. To measure the right hip abductor, the subject was instructed to lie down with his or her left shoulder flat on the table. The force plate was then adjusted so that the subject's right leg contacted the force plate with the hip in a neutral position with regard to abduction and adduction (1). The subject was instructed to push against the force plate, for 2–4 s, with maximum effort. This process was performed a total of three times, and the maximum and average force measures were recorded for later use. With the subject lying on his or her right side, measurements for the left hip abductor were obtained in the same manner (Fig. 1). To better isolate the gluteus maximus of the hip extensors, the knee was maintained in a flexed position during testing to minimize hamstring activation (25). To measure the right extensor, the subject was asked to lie on his or her stomach and slowly extend their right leg upwards until contact was made with the force plate. The force plate was adjusted so that the knee of the ipsilateral lower extremity was raised approximately 6–8 cm above the examination table, and flexed approximately 60–90 degrees. The subject was then prompted to push up against the force plate, for 2–4 s with maximal effort (Fig. 2). This process was performed a total of three times, and the maximum and average force measures were recorded. Left extensor strength was measured by performing the same procedures, as discussed above, but with the left leg. The subject's position during strength testing, discussed above, followed standardized techniques (25).

FIGURE 2—Measurement of the right hip extensor.

Over the course of the 1999–2000 competitive season, a certified strength and conditioning coach incorporated a core-strengthening program into each athlete's training program. Up until the time of the 1999 preparticipation physicals, no structured core-strengthening program had been instituted. Commencing after the 1999 preparticipation physicals, all athletes performed a 30- to 45-min program, four to five times per week in the preseason and two to three times per week during the season. The core-strengthening program included abdominal, paraspinal, and hip extensor strengthening. Exercises included isolated abdominal strengthening, incorporating sit-ups and pelvic tilts, to address both the rectus abdominis and abdominal obliques. Squats and lunges were utilized as exercises to emphasize multiple joint activation including the ankle, knee, and hip. These exercises focused on strengthening of proximal hip, quadriceps, and paraspinal musculature. Leg press was also utilized to strengthen the quadriceps and hamstring musculature along with the gluteus maximus. Strength training with free weights was incorporated into the program, and included dead lifts and hang cleans. Dead lifts require the athlete to squat and lift a barbell off the floor to waist level. Hang cleans require the athlete to lift a barbell to shoulder level and then accelerate the weight overhead utilizing quadriceps, hamstrings, and hip musculature to drive the weight upwards along with shoulder and elbow muscle groups in the upper extremities. Additionally, isolated back extension exercises using a roman chair from 45 degrees of flexion to neutral was incorporated into the program. Compliance of athletes in performance of the core-strengthening program was excellent, since participation was mandatory as per coaching staff with athlete strengthening information recorded and reviewed. Exercises were varied on different days in light of time constraints to the training program. An example of a single day strengthening program is provided (Fig. 3). To our knowledge, there was no difference in compliance with the strengthening program between students who did and did not develop LBP over the ensuing year.

Data Preparation and Analysis

Derivation of %ΔME and %ΔMA. The average and maximum value for each of the four hip muscles tested was computed from the three test repetitions obtained. Subsequent terms will be derived from only the left and right maximum abductor strength (LMA, RMA) and the left and right maximum extensor strength (LME, RME), since they are more appropriate to use in the representation of maximum muscle strength output than average values. Side-to-side strength differences in subjects' abductor and extensor muscles were computed as follows: $\Delta MA = RMA - LMA$: side-to-side strength differences of abductors; and $\Delta ME = RME - LME$: side-to-side strength difference of extensors.

As indicated by the above equations, a small value of ΔMA or ΔME indicates that side-to-side strength differences are minimal. Large values for ΔMA and/or ΔME indicate that a side-to-side muscle strength imbalance exists. A large positive or negative value for ΔMA or ΔME can be specifically interpreted as a stronger right side or left side, respectively. The ΔMA and ΔME are used to derive the percentage difference between left and right abductor muscles of the gluteus medius (%ΔMA) and left and right extensor muscles of the gluteus maximus (%ΔME) as follows: $\%\Delta MA = (\Delta MA/Max[RMA, LMA]) \times 100$; and $\%\Delta ME = (\Delta ME/Max[RME, LME]) \times 100$. The percentage difference allows for effective, easily interpreted observations of the extent of side-to-side difference, regardless of the absolute strength values. As previously mentioned, a positive or negative value can be specifically interpreted as a stronger right or left side, respectively. (Note that Max[RME, LME] means that the larger of the two values is used as the denominator.)

Another representation of side-to-side difference was also considered, since it had the advantage of normalizing strength with respect to weight. Data presented in this way, however, are not easily interpreted because derived results are in the form of very small, unitless numbers. Since both percentage difference and weight-normalized representations yielded similar results, it was decided that results would be better communicated with the more intuitive representation of the percentage difference.

RESULTS

The study population included different groups of NCAA Division I college athletes, from two different academic years, undergoing their preparticipation sports physical examinations. Additionally, information for hip extension strength is included for the 2000–2001 preparticipation physical, although no information regarding LBP is yet available. See Table 2 for numbers of athletes undergoing physicals in the 1998–1999, 1999–2000, and 2000–2001 academic years. The percentage of athletes participating in the study from 1998–1999 was 164 of 310 (53%), and in 1999–2000, 236 of 312 (76%). No accurate total is available for the 2000–2001 academic year, but 225 were evaluated for the purposes of this study. As participation in this study could not

Strengthening Record

ATHLETE'S NAME: ____ SPORT: _________ (Day #1) Start Date_______________

EXERCISE													
Dead Lift 3 x 8													
Hang Cleans 3 x 8													
Squats 3 x 8													
Leg Press 3 x 8													
Crunches 3 x 25													
Pelvic Tilts 3 x 25													
Back Extensions 3 x 15													

FIGURE 3—Single day strengthening compliance sheet.

be mandatory, as per IRB regulations, there was no way to control for the percentage of athletes per year who participated.

LBP Incidence in 1998–1999 versus 1999–2000

Athletes examined in the 1998–1999 and 1999–2000 preparticipation physical are assumed to, on average, have similar characteristics, since the core-strengthening program had not yet been instituted (Table 1). At the time of the 1999–2000 preparticipation physical, it is not believed that any factors exist that would, in general, cause the group of athletes from the 1998–1999 academic year and the 1999–2000 year to have significantly different results.

The incorporation of core strengthening after the 1999–2000 preparticipation physicals, however, is a factor that could conceivably have led to differences between athletes in the 1998–1999 and 1999–2000 academic years. To explore these possible differences, a chi square analysis was used to compare numbers of athletes that required treatment for LBP during the two consecutive academic years. Table 3 shows incidence of LBP in the 1998–1999 and 1999–2000 seasons.

In the 1999–2000 season, 14 of 236 (6%) athletes required treatment for LBP, as compared with 14 of 164 (8.5%) during the 1998–1999 season ($P = 0.3153$). Of male and female athletes, respectively, 7 of 162 (4.3%) and 7 of 74 (9.5%) required treatment of LBP after incorporation of core strengthening in the 1999–2000 season ($P = 0.12$). This compared with 8 of 101 (8%) male athletes and 5 of 63 (7.9%) female athletes who required treatment for LBP in the 1998–1999 season before the core-strengthening program was instituted ($P = 0.72$). No significant differences between incidence of LBP in males versus females existed in 1998 ($P = 0.72$) or in 1999 ($P = 0.12$). No significant differences in LBP occurrence were noted for females in 1998 versus 1999 ($P = 0.75$) or for males in 1998 versus 1999 ($P = 0.22$).

Changes in Athletes Participating in Two Consecutive Physicals

A subset of athletes had hip strength recorded in two consecutive preparticipation physicals. Paired *t*-tests were performed to compare preparticipation %ΔMA and %ΔME values between consecutive years. Of athletes screened during consecutive years, 30 females and 51 males were present at both 1998–1999 and 1999–2000 preparticipation physicals. Twenty-four females and 49 males were present at preparticipation physicals in both 1999–2000 and 2000–2001. Athletes participating in both 1998–1999 and 1999–2000 preparticipation physicals were found to have no significant differences in %ΔMA ($P = 0.5$) or %ΔME ($P = 0.15$) values. For students participating in both 1999–2000 and 2000–2001 physicals, however, a significant difference was observed in %ΔME values ($P = 0.0001$). Students in the 2000–2001 academic year tended to, on average, have significantly stronger right hip musculature, as compared with the previous year. Table 4 shows %ΔME values for athletes screened in consecutive years. Note that side-to-side strength imbalance exists in both years, and is even more prevalent in the 2000–2001 season. This observation will be discussed further. Hip abductor data were not collected in the 2000–2001 preparticipation physical; therefore, it is unknown whether %ΔMA varied between 1999–2000 and 2000–2001.

%ΔME and %ΔMA versus Occurrence of LBP over the Ensuing Year

For 1998–1999 and 1999–2000, statistical analysis was performed to determine whether %ΔMA and/or %ΔME were predictive factors in the development of LBP. Logistic regression was utilized to determine whether hip strength values are a factor in the occurrence of subsequent LBP.

TABLE 2. Number of athletes participating in preparticipation physicals.

	1998–1999	1999–2000	2000–2001
Total	164	236	225
Males	101	162	170
Females	63	74	55

TABLE 3. Incidence of LBP in 1998–1999 and 1999–2000.

	1998–1999 (%)	1999–2000 (%)
Total	14 of 164 (8.5)	14 of 236 (6)
Males	8 of 101 (8)	7 of 162 (4.3)
Females	5 of 63 (7.9)	7 of 74 (9.5)

TABLE 4. Comparison of %ΔME values in athletes participating in two consecutive annual physicals.

	Athletes Who Participated in Both 1998–1999 and 1999–2000				Athletes Who Participated in Both 1999–2000 and 2000–2001[a]			
	%ΔME 1998–1999		%ΔME 1999–2000		%ΔME 1999–2000		%ΔME 2000–2001	
	Mean (%)	SE	Mean (%)	SE	Mean (%)	SE	Mean (%)	SE
All	–4.7	2.1	–1.1	1.7	–2.2	1.9	9.1	2.5
Male	–4.5	2.8	–0.33	2.2	–0.72	2.4	8.4	2.6
Female	–5.0	2.9	–2.0	2.7	–5.4	2.8	10.6	5.5

[a] Significant difference between 1999–2000 and 2000–2001 values ($P = 0.0001$).
Note: %ΔME was derived by calculating difference between right and left hip strength and then dividing by the value of strength on the stronger side. To obtain the percentage difference, result multiplied by 100.

Since the outcome (i.e., incidence of LBP) is binary and the independent variables (i.e., %ΔME and %ΔMA) are continuous, logistic regression is appropriate. Low incidence of LBP during the academic year resulted in very few data points in the LBP group. In order to verify that imbalanced data did not compromise the ability of a valid logistic regression model with these data, the Hosmer-Lemeshow goodness of fit test was used to ascertain that the generated model is, in fact, an appropriate fit. All logistic regressions performed, for both male and female athletes, were valid models according to the Hosmer-Lemeshow goodness of fit test. Furthermore, the likelihood test, which is powerful for a small number of samples, is used to generate the P values reported in the results. It should be kept in mind, however, that because of the paucity of LBP, a significant result of the likelihood test only suggests the predictive value of %ΔME and %ΔMA as opposed to proving the predictive values of %ΔME and %ΔMA absolutely. Logistic regression results for males and females are reported below.

Female athletes. As shown in Figure 4, logistic regression demonstrated a significant difference in the mean value of %ΔMA ($P = 0.009$), during the 1999–2000 season, in female athletes who required treatment for LBP. As demonstrated in Figure 4, as the left side becomes stronger, the probability that no LBP treatment is needed increases. Even when athletes having a previous history of LBP are excluded, results are significant ($P = 0.04$). No significant differences between the females with and without LBP were observed in mean values of %ΔME ($P = 0.98$), as observed in Figure 5. This was in contradistinction to results of the 1998–1999 season, where a significant difference in %ΔME ($P = 0.05$) was observed between those females with and without LBP (Fig. 6) (28). No differences were noted in mean values of %ΔMA ($P = 0.35$) in 1998–1999, as shown in Figure 7 (28). In Figures 4–7, examples are provided to facilitate interpretation. When referring to these figures, a positive or negative value can be specifically interpreted as a stronger right or left side, respectively.

Male athletes. %ΔME ($P = 0.29$) or %ΔMA ($P = 0.38$) were not significantly different in male athletes who had occurrence of LBP in 1999–2000. These results were no different than that noted in 1998–1999: %ΔME ($P = 0.51$) and %ΔMA ($P = 0.30$), before incorporation of the core-strengthening program, were also found not to be predictive of LBP in males.

DISCUSSION

Core strengthening and LBP incidence. LBP is a common problem in any sport that requires significant rotatory or twisting motions, repetitive flexion, and/or extension or where previous lower extremity injury may have altered the normal mechanics of the kinetic chain (4,6,16,19,27,31). Female athletes have been demonstrated to be more likely to suffer from its occurrence than males (7,10,21,26,29,30). According to NCAA Injury Surveillance Data 1997–1998, female athletes were almost twice as likely to sustain injury to their lower backs than males. In women's basketball, the low back was the third most commonly injured body region after the ankle and knee. In women's volleyball and soccer, low back injury was the most and second most common injury sustained during the spring season (29). According to NCAA Injury Surveillance Data 1998–1999, low back injury was the most common injury in

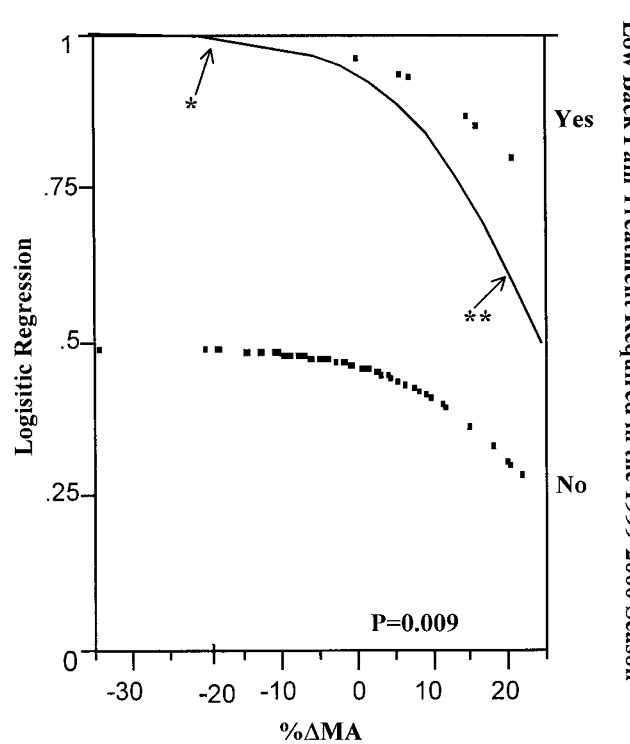

FIGURE 4—Incidence of LBP treatment (1999–2000) as a function of %ΔMA in female athletes. *For %ΔMA = −20 (i.e., left > right), the probability that no LBP treatment is needed is approximately 0.99. **For %ΔMA = 20 (i.e., right > left), the probability that no LBP treatment is needed is approximately 0.62.

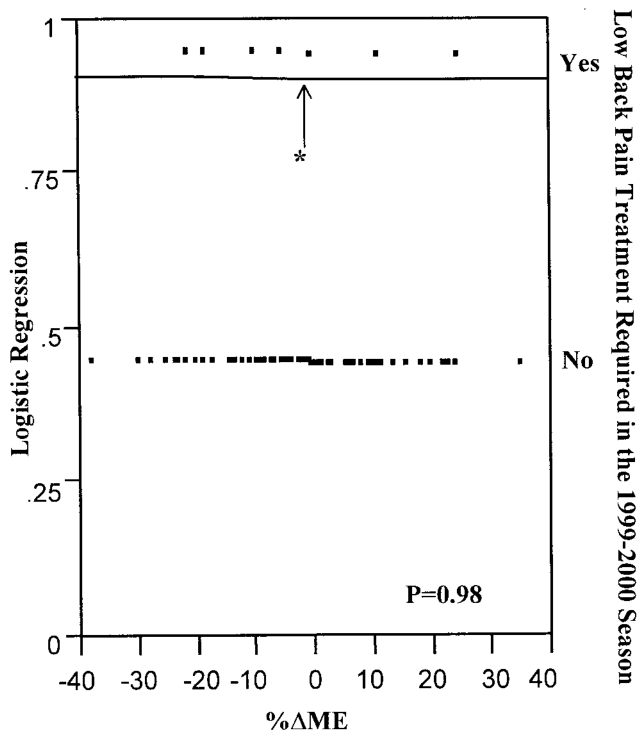

FIGURE 5—Incidence of LBP treatment (1999–2000) as a function of %ΔME in female athletes. *Regardless of the value of %ΔME, the probability that no LBP treatment is needed is approximately 0.9.

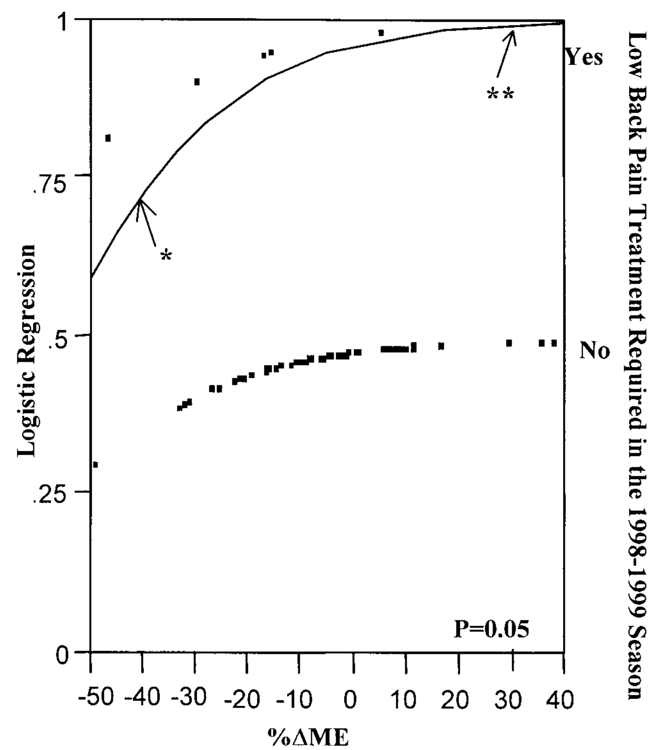

FIGURE 6—Incidence of LBP treatment (1998–1999) as a function of %ΔME in female athletes. *For %ΔME = −40 (i.e., left > right), the probability that no LBP treatment is needed is approximately 0.74. **For %ΔME = 30 (i.e., right > left), the probability that no LBP treatment is needed is approximately 0.99.

women's gymnastics during competition (30). In addition, it was the second and third most common injury in practice, in women's gymnastics, field hockey, and volleyball, respectively (30). Nadler et al. previously demonstrated 8% more female athletes reporting LBP than male athletes (24). Gender difference in LBP occurrence may be a result of differences in gait, playing style, and pelvic anatomy, but at the present time, the exact reasons remain unknown (7,10,13,19).

Although no significant differences were found in LBP occurrence between the 1998–1999 and 1999–2000 academic years, some interesting trends were observed. Males had a nonsignificant reduction in LBP occurrence after incorporation of the core-strengthening program. Specifically, LBP occurrence in male athletes decreased from 8 of 101 (8%) to 7 of 162 (4.3%). Although these present data are not sufficient to conclusively prove the role of the core strengthening in LBP reduction, they certainly demonstrate the importance of further studies to better understand the effects or advantages of the core-strengthening program in collegiate athletes. Interestingly, female incidence of LBP slightly increased after incorporation of the core-strengthening program. Specifically, female LBP occurrence increased from 5 of 63 (7.9%) to 7 of 74 (9.5%). It is conjectured that this increase may be an indication that the core-strengthening program may need modification to better accommodate female subjects. Once again, the small numbers of individuals who actually developed LBP makes any conclusions difficult.

Core strengthening and hip extensors. Hip extensors (gluteus maximus) play a major role in stabilizing the pelvis during trunk rotation, or when the center of gravity is grossly shifted. Several studies support hip extensor involvement in individuals with LBP (18,22). Kankaanpaa et al. demonstrated increased fatigability of the gluteus maximus in individuals with chronic LBP (18). Leinonen et al. also demonstrated the gluteus maximus to be more easily fatigued in those with nonspecific chronic LBP, but noted improvement in the latency of firing in the gluteus maximus after rehabilitation (22). Although not fully understood, side-to-side strength differences of the hip extensor muscles have been attributed to both injury and/or specialized training/rehabilitation (27). Hewett et al. found that, in response to a jump training program, female subjects had a 44% increase in hamstring muscle power on the dominant side and only a 21% increase on the nondominant side (11). Our data for 2000–2001 demonstrated a significant increase in right hip extensor strength after incorporation of the core-strengthening program. This strength increase of the right hip extensors, the dominant side for 90% (192 of 213) of athletes in our study, is consistent with the results of Hewett et al.'s study. A similar response to training would be expected for both the hamstrings and gluteus maximus, as these two muscle groups work synergistically to extend the hip and stabilize the pelvis (17). Weakness of the right hip extensors in female athletes was previously noted in those with a history of LBP and in those who ultimately developed LBP (27,28). Therefore, the tendency for the core-strengthening program to increase right side extensor strength may

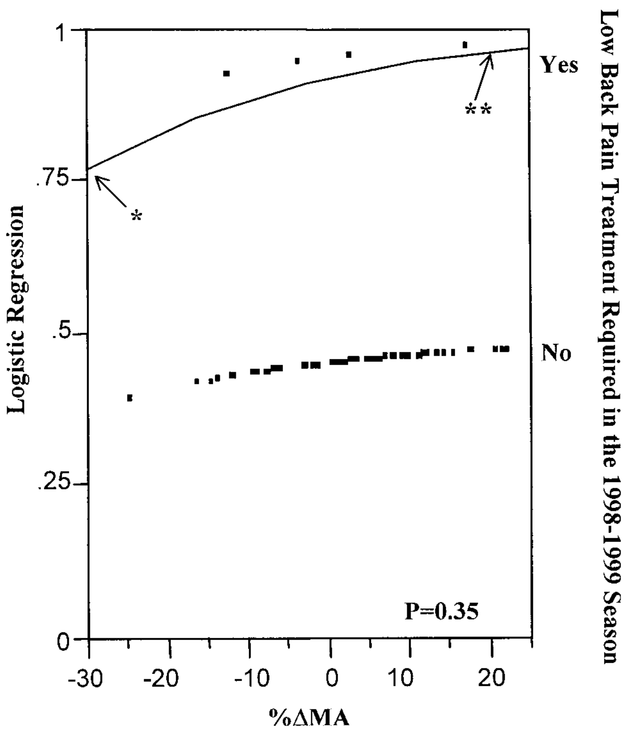

FIGURE 7—Incidence of LBP treatment (1998–1999) as a function of %ΔMA in female athletes. *For %ΔMA = −30 (i.e., left > right), the probability that no LBP treatment is needed is approximately 0.76. **For %ΔMA = 20 (i.e., right > left), the probability that no LBP treatment is needed is approximately 0.94.

be perceived as potentially beneficial. We are uncertain why hip extensor differences noted in 1999–2000 no longer influenced the development of LBP in female athletes (Fig. 5) as it did in 1998–1999 (Fig. 6). As shown in Figure 5, regardless of %ΔME, the probability that a subject would not develop LBP is high in 2000–2001. It is speculated that this occurrence may be evidence of some success of the core-strengthening program.

Male athletes demonstrated no significant relationship with %ΔME and LBP occurrence in 1998–1999 or 1999–2000. As mentioned previously, a statistically nonsignificant reduction in LBP occurrence after incorporation of the core-strengthening program was observed. This decline in LBP may also be a result of the positive effects of core strengthening on function of the hip extensors. Alternatively, abdominal muscle strength improvement may have affected LBP occurrence (12,32,33). More investigations are needed, however, because of the low incidence of LBP in this population.

Core strengthening and hip abductors. Biomechanically, the hip extensors and abductors play a major role in all ambulatory activities, working synergistically to stabilize the pelvis and transfer forces from the lower extremities to the spine (17,23,31). Jaramillo et al. and Beckman and Buchanan noted strength and firing differences in the hip abductors in individuals with distal involvement of the lower extremities (1,14). Johnson observed that excessive hip slide, and sports that require high-speed rotation of the hip abductors, may predispose to low back injury (16). Nadler et al. noted that, for both male and female athletes (Fig. 7), there was no association between differences in side-to-side hip abduction strength and the likelihood of LBP occurrence in the ensuing 1998–1999 academic year (28). This outcome remained consistent for male athletes, after incorporation of core strengthening (1999–2000), but not for female athletes (28). As shown in Figure 4, female athletes with weaker left abductors were significantly more likely to develop LBP. Conversely, female athletes with stronger left abductors were significantly less likely to develop LBP. Lateral dominance within the lower extremities may help to explain this finding. Beling et al. found that the left leg is generally used for stance and posture, whereas the right leg is used for more coordinated function such as kicking and jumping (2). The hip abductor functions in midstance to stabilize the pelvis, preventing a downward inclination (Trendelenburg sign) during single leg stance. In the face of hip abduction weakness, increased muscular requirements of the lateral trunk stabilizers (i.e., quadratus lumborum) are necessary in order to better stabilize the pelvis. In light of issues of lateral dominance and an understanding of the kinesiology of pelvic and trunk musculature, increased abductor strength on the left side may theoretically help to prevent LBP occurrence.

Although the exact mechanism for these different findings are not known at this time, we speculate that the tendency of the core-strengthening program to primarily concentrate on extensor training (Fig. 4) may have contributed to the results. Isolated strengthening of the extensors may have resulted in some inhibition or neglect of the hip abductors, causing female athletes with weak left abductors, in particular, to be more prone to development of LBP. As noted previously, the hip abductor helps to maintain postural stability during midstance. Kollmitzer et al. demonstrated focused extensor training to result in decreased postural stability, in support of this concept (20). Because of the limitations of our data, in terms of study design and paucity of athletes with LBP occurrence, this discussion is speculative in nature. This theory would need to be clarified in a carefully modeled study. Overall, the need for both a more gender-specific strengthening program and the advantage of a more well-rounded and less-specific strengthening program may be implied by these data. Since abductor data were not collected during the 2000–2001 preparticipation physical, we are unable to identify whether the core-strengthening program had any influence on the average side-to-side differences in abductor strength that were previously observed.

There are several limitations noted in this pilot study. The number of athletes who required treatment for LBP was small, which could be secondary to poor record keeping by the athletic training staff, poor reporting by the athletes, better preseason conditioning, or as yet unknown factors. The changes that may have occurred in hip strength over the course of conditioning, as well as the effects of concomitant lower extremity injury during the competitive season, were not taken into account, which may have also influenced the results. Finally, other causes for LBP unrelated to hip strength could also have influenced the results, including concomitant medical conditions, lumbar disk injury, LBP secondary to factors outside of the sports season (i.e., work, school, and leisure activities), and previously unknown psychosocial issues. Overall, we feel the results of this study are noteworthy, but require further validation in a larger multicenter study.

CONCLUSION

Core strengthening has been advocated and utilized for conditioning athletes for years without any research to support an effect. A supervised core-strengthening program emphasizing the muscles of the trunk, spine, and hip extensors resulted in a statistically nonsignificant reduction in LBP in male athletes. Although the core program had no statistically significant effect on LBP occurrence, it may have been a factor in altering the dynamics of side-to-side hip strength in such a way as to have been advantageous in reducing risk for future LBP development. No reduction in LBP occurrence was observed in female athletes after inclusion of core strengthening, which may be related to the need for more isolated hip abduction strengthening in female athletes. The conclusions of the present study are limited secondary to the overall small numbers of subjects who developed LBP. Larger scale studies are needed both to validate the results of this study and to increase the overall understanding of the effects of core-strengthening programs.

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REFERENCES

1. Beckman, S. M., and T. S. Buchanan. Ankle inversion injury and hypermobility: effect on hip and ankle muscle electromyography onset latency. *Arch. Phys. Med. Rehabil.* 76:1138–1143, 1995.
2. Beling, J., G. A. Wolfe, K. A. Allen, and J. M. Boyle. Lower extremity preference during gross and fine motor skills performed in sitting and standing postures. *J. Orthop. Sport Phys. Ther* 28:400–404, 1998.
3. Biering-Sorensen, F. Physical measurements as risk indicators for low-back trouble over a one-year period. *Spine* 9:106–119, 1984.
4. Brody, D. M. Running injuries: prevention and management. *Clin. Symp.* 39:1–36, 1987.
5. Bullock-Saxton, J. E. Local sensation changes and altered hip muscle function following severe ankle sprain. *Phys. Ther* 74:17–28, 1994.
6. Chard, M. D., and M. A. Lachmann. Racquet sports: patterns of injury presenting to a sports injury clinic. *Br. J. Sports Med.* 21:150–153, 1987.
7. Clarke, K. S., and W. E. Buckley. Women's injuries in collegiate sports: a preliminary comparative overview of three seasons. *Am. J. Sports Med.* 8:187–191, 1980.
8. Devita, P., P. B. Hunter, and W. A. Skelly. Effects of a functional knee brace on the biomechanics of running. *Med. Sci. Sports Exerc.* 24:797–806, 1992.
9. Giles, L. G. F., and J. R. Taylor. Low-back pain associated with leg length inequality. *Spine* 6:510–521, 1981.
10. Haycock, C. E., and J. V. Gillette. Susceptibility of women athletes in injury: myths vs. reality. *JAMA* 236:163–165, 1976.
11. Hewett, T. E., A. L. Stroupe, T. A. Nance, and F. R. Noyes. Plyometric training in female athletes: decreased impact forces and increased hamstring torques. *Am. J. Sports Med.* 24:765–773, 1996.
12. Hodges, P. W., and C. A. Richardson. Delayed postural contraction of the transversus abdominis in low back pain associated with movement of the lower extremity. *J. Spinal Disord.* 11:46–56, 1998.
13. Inman, V. T. Functional aspects of the abductor muscles of the hip. *J. Bone Joint Surg.* 29:607–619, 1947.
14. Jaramillo, J., T. W. Worrell, and C. D. Ingersoll. Hip isometric strength following knee surgery. *J. Orthop. Sport Phys. Ther* 20:160–165, 1994.
15. Jeng, S. Lumbar spine stabilization exercise. *Hong Kong J. Sport Med. Sports Sci.* 8:59–64, 1999.
16. Johnson, H. Stressful motion: golfers at high risk for low back pain. *Sports Med. Update* 14:4–5, 1999.
17. Joseph, J., and A. Nightingale. Electromyography of muscles of posture: thigh muscles in males. *J. Physiol.* 126:81–85, 1954.
18. Kankaanpaa, M., S. Taimela, D. Laaksonen, O. Hanninen, and O. Airaksinen. Back and hip extensor fatigability in chronic low back pain patients, and controls. *Arch. Phys. Med. Rehabil.* 79:412–417, 1998.
19. Kerrigan, D. C., M. K. Todd, and U. Della Croce. Gender differences in joint biomechanics during walking: normative study in young adults. *Am. J. Phys. Med. Rehabil.* 77:2–7, 1998.
20. Kollmitzer, J., G. R. Ebenbichler, A. Sabo, K. Kerschan, and T. Bochdansky. Effects of back extensor strength training versus balance training on postural control. *Med. Sci. Sports Exerc.* 32:1770–1776, 2000.
21. Lanese, R. R., R. H. Strauss, D. J. Leizman, and A. M. Rotondi. Injury and disability in matched men's and women's intercollegiate sports. *Am. J. Public Health* 80:1459–1462, 1990.
22. Leinonen, V., M. Kankaanpaa, O. Airaksinen, and O. Hanninen. Back and hip extension activities during trunk flexion/extension: effects of low back pain and rehabilitation. *Arch. Phys. Med. Rehabil.* 81:32–37, 2000.
23. Lyons, K., J. Perry, J. K. Gronley, L. Barnes, and D. Antonelli. Timing and relative intensity of hip extensor and abductor muscle action during level and stair ambulation. *Phys. Ther.* 63:1597–1605, 1983.
24. McGill, S. M., A. Childs, and C. Liebenson. Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. *Arch. Phys. Med. Rehabil.* 80: 941–944, 1999.
25. Nadler, S. F., M. L. DePrince, N. Hauesien, G. A. Malanga, T. P. Stitik, and E. Price. Reliability of a portable dynamometer anchoring station for the measurement of strength of the hip extensors and abductors. *Arch. Phys. Med. Rehabil.* 81:1072–1076, 2000.
26. Nadler, S. F., K. D. Wu, T. Galski, and J. H. Feinberg. Low back pain in college athletes: a prospective study correlating lower extremity overuse or acquired ligamentous laxity with low back pain. *Spine* 23:828–833, 1998.
27. Nadler, S. F., G. A. Malanga, T. P. Stitik, and M. L. DePrince. The relationship between lower extremity injury, low back pain, and hip muscle strength in male and female collegiate athletes. *Clin. J. Sport Med.* 10:89–97, 2000.
28. Nadler, S. F., G. A. Malanga, J. H. Feinberg, et al. The relationship between hip muscle strength and low back occurrence in collegiate athletes: a prospective study. *Am. J. Phys. Med. Rehabil.* 80:572–577, 2001.
29. NCAA Injury Surveillance System (1997–1998). Overland Park, KS: National Collegiate Athletic Association, 1998.
30. NCAA Injury Surveillance System (1998–1999). Overland Park, KS: National Collegiate Athletic Association, 1999.
31. Nicholas, J. A., R. B. Grossman, and E. B. Hershman. The importance of a simplified classification of motion in sports in relation to performance. *Orthop. Clin. North Am.* 8:499–532, 1977.
32. Norris, C. M. Abdominal muscle training in sport. *Br. J. Sports Med.* 27:19–27, 1993.
33. Pollock, M. L., S. H. Leggett, J. E. Graves, A. Jones, M. Fulton, and J. Cirulli. Effect of resistance training on lumbar extension strength. *Am. J. Sports Med.* 17:624–629, 1989.