THE CHANGES IN STRENGTH, POWER AND ASSOCIATED FUNCTIONAL VARIABLES IN THE AUSTRALIAN WOMEN'S SOCCER TEAM DURING THE 12 MONTH PREPARATION FOR THE SYDNEY 2000 OLYMPIC GAMES

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The assessment of strength and power and the relationship of these measures to functional variables such as sprint speed and vertical jump (VJ) ability are understood poorly, particularly when dealing with a long-term preparation for a major event.

The results of this research suggest that a number of isoinertial speed strength measures are sensitive to aspects of a training program. Further results provide a question mark over the role of maximal strength in the development of high velocity functional movements.

KEYWORDS: soccer, strength assessment, training prescription, velocity specific adaptations, functional performance, long-term preparation.

INTRODUCTION

Preparing athletes for participation in major events involves an extended training period (Balyi 1999). During this time, it is likely that athletes undergo a number of changes to their physical capacities. Despite improvements in capacity being a goal of most training programs, the extent to which this occurs over a period of twelve months or greater has been reported infrequently.

The limited amount of information available on changes in strength and power capacities may be due to a number of reasons. Firstly, there is debate in the scientific community over the most appropriate method of measuring strength and power (Abernethy et. al. 1995). Measuring strength qualities via weightlifting type tasks, isokinetic dynamometry, and isoinertial speed strength assessment have all been proposed as useful and legitimate (Murphy 1996; Logan et. al. 2000).

Secondly, the role of underlying capacities of strength and power in functional performance is somewhat questionable. For example, the role of maximal strength as a determinant in the ability of female soccer players to sprint and jump is largely unknown.

Close examination of the changes that occur in a number of physiological variables throughout an extended preparation may give some insight into the role of strength and power in functional performance.

REVIEW OF LITERATURE

Physiological Assessment of Soccer Players

It would appear that soccer players require a range of fitness capacities to be successful (Tumilty 2000). It has been shown that results on anthropometric and performance tests are very good indicators for selection in National squads (Tumilty 2000). It has also been suggested that a certain level of performance on the following tests may indicate a likelihood of success at the elite level and that all are appropriate for both male and female soccer athletes (Tumilty 2000).

- Anthropometry (sum of 7 site skinfolds)
- Vertical Jump (countermovement)
- Sprints (5m, 10m, 20m)
- Aerobic Power (multistage fitness test)

Measuring Strength and Power

Abernethy et al. (1995) suggested that there are four main purposes of strength and power assessment:

1. Quantify the relative significance of strength and power to various athletic events and tasks.
2. Identify the specific deficiencies in muscular function to improve individual deficiencies.
3. Identify individuals who may be suited to particular sports or events.
4. Monitor the effects of training and rehabilitation programs.

There is considerable controversy surrounding the validity of many tests of muscular strength and power (Abernethy et. al. 1995). For example, Murphy and Wilson (1997) concluded that tests of muscular function could not be used to monitor training induced changes in performance. These researchers suggested that changes in performance, rather than changes in tests of muscle function should be used to determine the effectiveness of training.

As specific sporting movements are hard to imitate, assessment of strength and power is often conducted using non-specific tasks (Abernethy et. al. 1995). As a result of the desire to measure muscle function and its role in athletic performance, a number of test modalities utilising various contraction modes have been developed for this purpose. Isometric, Iskokinetic, and isoinertial testing have all been proposed as legitimate assessment methods. However, questions exist regarding the relationship of results on these tests to sporting movements (Wilson and Murphy 1995, Wilson 2000, Wrigley and Strauss 2000, Murphy et. al. 1994, Logan et. al. 2000, Baker et. al. 1994; Pryor et. al. 1994).

Dynamic Isoinertial Speed Strength Testing

Isoinertial dynamic speed strength assessment typically involves the use of a force platform to generate force-time curves (Pryor et. al. 1994; Wilson et. al. 1995). The range of exercises that can be assessed using this method are quite limited, which has resulted in most research involving a squat jump movement or bench press throw (Pryor et. al. 1994; Wilson et. al. 1995, Murphy and Wilson 1996). This type of testing can provide measures on a number of aspects of speed strength including Starting Strength, Maximum Rate of Force Development, and Maximum Dynamic Strength.

Little published research exists examining the relationship between isoinertial speed strength and performance but some authors have found a relationship between these measures and functional performance (Pryor et al. 1994).

Methods of Speed, Strength and Power Development

Determining the most effective methods for the development of strength, speed, and power is difficult. Research in this area is contradictory and there is a lack of precise understanding of the underlying factors responsible for the development of these components. However, it is generally accepted that both neural and hypertrophic factors combine to produce improvements in performance (Bloomer and Ives 2000, Komi 1986, Komi 1998).

A key question in the development of strength and power capacities is their transfer to functional athletic tasks. It has been suggested that training be broken into phases of different emphasis to develop the specific capacities required for performance (Baker 1996). The use of various stimuli have been proposed, including weight training, plyometric training, explosive weight training, and weight training utilising the load that maximises mechanical power output (Wilson et. al. 1993).

METHODS

All subjects in this study were current members of the Australian and/or AIS Women's Soccer Teams (*n* = 16, Age 23.48± 5.40 years, Height 167.7± 6.5 cm, Weight 62.76± 6.53 kg).

Data was collected on three (T1, T2, and T3) occasions between October 1999 and August 2000. A change was considered to have occurred if the score varied by more than the *CV* established in reliability testing. Data collection was divided into three categories:

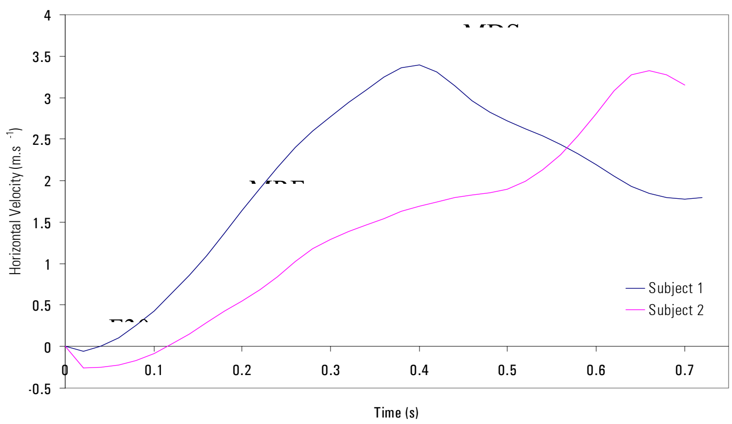
Physiological Testing: 5 m, 10 m, 20 m sprint, Vertical Jump (VJ) and 20 m Shuttle Run.

3 Repetition Maximum Strength Testing (3RM): Leg press, Bench press, and Chin ups.

Isoinertial Speed Strength Testing in 3 jump conditions: Squat Jump (SQJ), Controlled Counter Movement Squat Jump to 120° knee flexion (CCMJ) and Self Select Counter Movement Squat Jump (SSCMJ). The following measurements were taken for each trial of the three jump conditions and determined to be reliable.

Maximum Dynamic Strength (MDS): peak force generated during the dynamic phase of the movement, measured in kg.
MDStrength relative to body mass (MDS/BM): maximum dynamic strength relative to body weight.
Time to MDS (Time to MDS): time taken to reach maximum dynamic strength, measured in ms.
Maximum Rate of Force Development (MRFD): the steepest gradient of the force time curve over a 5 ms period, measured in N/s.
Time to MRFD: time taken to reach MRFD, measured in ms.

Figure 1. A Typical SQJ Force-time curve.



RESULTS

3RM Strength

3RM Leg press increased from T1-T3 in 89% of subjects (Figure 2.) whilst the 3RM Bench press score increased in 42% of subjects during the same time.

Isoinertial Speed Strength

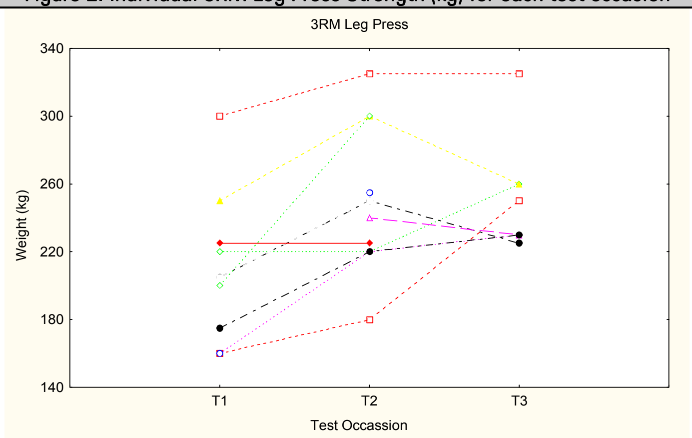
Squat Jump

Both the SQJMDS and SQJMDS/BM (Figure 3.) improved across the period of the study with the greatest improvements occurring from T2-T3. The greatest changes in SQJ Time to MDS occurred between T1 and T2. SQJMRFD scores increased in the majority of subjects when comparing all test occasions.

Controlled Countermovement Jump

CCMJMDS increased in a greater number of subjects from T1-T3 (67%) and T2-T3 (58%) than from T1-T2 (30%). The MDS/BM score followed an almost identical manner. CCMJMRFD scores increased across the period of the study with the greatest number of subjects improving MRFD between T1 and T2.

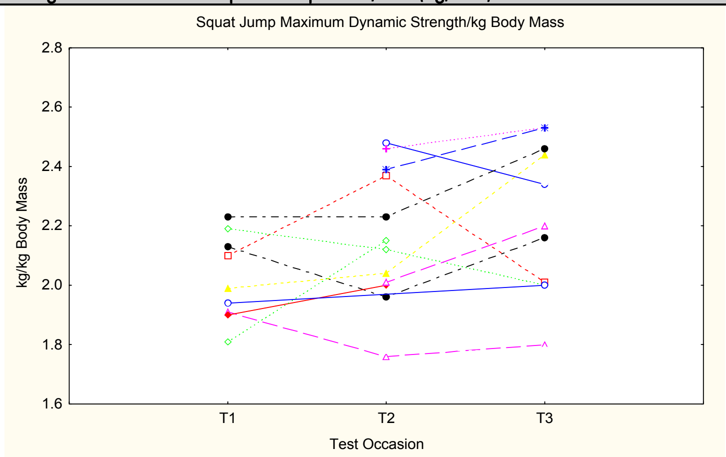
Figure 2. Individual 3RM Leg Press Strength (kg) for each test occasion



Self Select Countermovement Jump

The period from T1-T3 produced an improvement in SSCMJMDS by 78% of subjects with analysis of other time periods showing a slightly smaller number to have improved in this measure. SSCMJMDS/BM also increased in the 78% of subjects from T1-T3. SSCMJMRFD improved markedly from T1-T2 with 80% of subjects increasing their score. A large number (78%) also improved from T1-T3 with 50% of subjects improving from T2-T3.

Figure 3. Individual Squat Jump MDS/BM (kg/BM) for each test occasion



Correlations

T1

At T1, significant correlations existed between the 5 m and 10 m sprint, 10 m and 20 m sprint and 20 m sprint and VJ. The 5 m sprint was significantly correlated to SQJMRFD (r=0.83, p=0.021) and CCMJMDS (r=-0.94, p=0.001) whilst the 10 m sprint and CCMJMDS/BM were significantly correlated (r=-0.85, p=0.014). The 20 m sprint and SSCMJMDS/BM showed a significant correlation (r=-0.77, p=0.042)

T2 and T3

At T2 and T3 no significant correlations existed between the 3RM Leg press or Isoinertial speed strength measures and functional variables. At both test occasions, 5 m and 10 m, 5 m and 20 m, and 10 m and 20 m sprints were significantly correlated.

DISCUSSION

Program Goals and Overall Program Design

The goal of the T1-T3 training program was to produce improvements in Functional performance with a peak at the Sydney 2000 Olympic Games. In order for this to occur the twelve month period leading up to the Olympics was divided in phases with training sessions following a gradual progression towards more specific training. This type of approach has been demonstrated previously to bring about superior improvements in performance than a non-periodised system (Fleck and Kraemer 1987; Stone. et al. 1999; Stone et. al. 1999; Wathen 1994).

T1-T3

Data from this period suggests a trend towards specific adaptation and its expression in functional performance. This is not surprising given the increasing specificity of the program approaching T3 (Baker et. al. 1994; Murphy et. al. 1994; Pryor et. al. 1994). As well as improvements in functional performance it is likely that some aspect of the training program was responsible for the increases seen in various aspects of isoinertial speed strength. Of particular interest is the greater number of subjects to show improvement in these capacities as the contribution of the stretch shorten cycle (SSC) increased to the jump condition (e.g. SQJ v SSCMJ).

The periodisation of the current study involved a more rapid progression towards specific movements than suggested in traditional models (Wathen 1994; Wathen 1994) but was successful in producing changes in functional performance.

T1-T2

The improvements in sprint speed seen at T2 are likely to have been influenced by the same factors that caused improvements in 3RM Leg press, MDS/BM, and MRFD measures during this time. Training programs utilising a variety of methods including plyometrics and contrast loading to produce improvements in performance similar to those seen at T2 have been demonstrated previously (Harris et. al. 2000; Rimmer and Sleivert 2000; Wilson et. al. 1993).

The smaller number of subjects to improve in the 5 m sprint as compared to the large number to show improvement in the 3RM Leg press raises the question of specificity of adaptation and transfer of training to the athletic environment. The question of the importance of maximal strength to sprint speed highlighted by the current research, has been raised by others (Baker and Nance 1999; Young et. al. 1995).

In the present study, MDS/BM increased in a large number of subjects whilst only a small percentage improved their 5 m sprint times. Baker and Nance (1999) and Young et. al. (1995) suggested that relative strength was an important factor in short sprint speed. This suggests that MDS/BM as measured during an isoinertial speed strength task represents the measurement of a different quality than measurement of relative strength determined using a weightlifting type task.

Despite improvements in VJ performance by over half the group, greater improvement was expected considering the amount of jumping movements in the training program. Most of the jumping movements in the training program were aimed at minimising ground contact time rather than maximising jump height. This suggests that changes in underlying muscular capacities rather than changes in technical efficiency or familiarity with the movement were responsible for VJ improvements.

The improvement by more subjects in the SSCMJMDS condition than the SQJMDS and CCMJMDS conditions may be due to the close relationship between the movement patterns of the training program and the SSCMJMDS. The effect of specific training protocols has been demonstrated previously (McBride et. al. 1999).

The number of subjects to display increases in the MRFD capacity increased as the contribution of the SSC to the jump condition increased. This provides further support for the concept of specificity of adaptation. Improvements in MRFD have been shown to occur as a result of training with either attempted acceleration or slow controlled movements (Young and Bilby 1993). However, this conclusion should be viewed with caution as the testing mode was isometric rather than isoinertial.

A factor for consideration is the status of an athlete when they commence a training program and therefore the influence of that training program. Despite high initial 3RM Leg press scores and involvement in an elite National Squad program these athletes can be considered only minimally to moderately trained, particularly in relation to speed strength tasks.

T2-T3

Changes in functional measures occurred in less subjects than during the T1-T2 period. It is suggested that this is related to the improvements seen from T1-T2 and the in-season nature of the T2-T3 period is likely to have decreased the potential for change from T2-T3. This view is supported by Koutedakis (1995) who reported no change in many fitness parameters in elite athletes when comparing off-season and in-season measures.

Interestingly, during a period of frequent high level competition and intense on field training, 3RM Leg press scores continued to increase in many of the subjects. This seems related to low initial 3RM scores therefore allowing continued improvement and/or an emphasis by the subjects on high force-low velocity movements rather than high speed movements.

It was unexpected that only 50% of subjects would improve their MDS in the SSCMJ condition whilst greater numbers increased their MDS score in the SQJ and CCMJ. This is particularly the case as the training program undertaken between T2 and T3 included a number of exercises with a contribution to the concentric phase from the SSC and a self-selected angle of knee flexion. A plausible explanation for these results is the approach of individual subjects to the training stimulus. Under utilisation of the SSC in training exercises by performing them too slowly would increase subject familiarity with tests involving a limited contribution from the SSC and therefore enhance the likelihood of improved results on these tests.

It was expected that large numbers of subjects would improve their MRFD, particularly in the SSCMJ condition. As this did not occur it suggests that the training and test environments were sufficiently different, therefore preventing the display of velocity specific adaptations developed in training. The subjects appear to have trained at a speed slower than the SSCMJ speed and so shown little improvement on this task (Wilson et. al. 1995). The lack of change evident in the SSCMJMRFD variable, provide strong evidence that training programs aiming to improve MRFD must ensure that high velocity movements are the dominant stimulus. It would be advantageous for this type of training to utilise some method of measuring speed of contraction or ground contact time.

CORRELATIONS

T1

The high correlations between the 5 m and 10 m sprints suggests that performance over the longer distance is influenced by performance over the shorter distance. This may also be true for the strong relationship displayed between the 10 m and 20 m sprint distances. As no significant relationship existed between the 5 m and 20 m sprints, different muscular capacities are suggested to influence performance over these distances.

As a result of no significant relationship between the 5 m and 20 m sprints it is logical to expect the VJ to be more closely related to the shorter sprint distance. However, this was not the case, as a significant correlation existed between the VJ and 20 m sprint. Previous research (Young and Pryor 2001) has found that maximum speed correlates significantly with performance on a drop jump (a measure of reactive strength). This lends support to the expectation of a relationship between tasks involving minimal reactive strength components (i.e. VJ and 5 m and 10 m sprints).

CCMJMDS showed a strong correlation to 5 m sprint time whilst CCMJMDS/BM was correlated significantly to 10 m sprint performance and SSCMJMDS/BM was correlated to 20 m sprint time. These relationships suggest that as sprint distance increases, relative MDS (especially when expressed with a contribution from the SSC) is more important that absolute MDS. MDS can be considered most important to short sprints. However Young and Pryor (2001) suggest relative strength is most important in short sprints and that absolute values become more important for longer sprints. It is likely that the method of strength assessment (dynamic v weightlifting) influences these relationships.

There was no relationship between 3RM strength and any sprint distance or the VJ. The lack of relationship between VJ and 3RM strength has been reported elsewhere (Baker et. al. 1994). This finding raises questions about the role of maximum strength in high velocity functional performance when movement of the athletes own body without external resistance is the goal.

T2 and T3

The nature of the relationships between variables changed dramatically when comparing T1 to T2 and T3. On the later test occasions no significant relationships existed between measures of isoinertial speed strength and functional performance. This lends support to the notion that the effectiveness of training should be based on changes in performance rather than on measures of muscle function (Murphy and Wilson 1997). It also raises further questions about the relationship between various strength qualities and performance (Young et. al. 1999).

CONCLUSIONS AND PRACTICAL RECOMMENDATIONS

The hybrid nature of both the sport of soccer and the nature of the training stimulus may have contributed to the improvements in both tests of underlying muscular qualities and those of functional performance. A training program that contains an emphasis on a narrow spectrum of capacities may produce superior results in those capacities than the program undertaken in this study.

The precise nature in which a training program is executed seems likely to influence the specific neuromuscular response. It is reasonable to conclude from the results of the current study that an over emphasis on force dominated exercises at the expense of lighter load velocity dominated movements limits the development of speed strength capacities as measured by isoinertial speed strength assessment.

Despite being considered elite athletes, the results of this study suggest that the subjects were relatively poorly trained in speed strength capacities at the start of the data collection period. As the level of performance on speed strength dominated tasks increases, a more specific stimulus is needed to cause the desired adaptation.

Responses to a long term preparation for a major event are very individual in nature. Determining individual limitations to performance is likely to be the key to designing programs to allow an individual athlete to achieve the greatest change in performance. The most appropriate periodisation model (in terms of manipulation of volumes, intensities and exercises) remains largely unproven.

A number of measures of isoinertial speed strength, particularly those that closely mimic the training stimulus are sensitive to aspects of the training program. More work is required to improve the test-retest reliability of these measures.

The role of maximum strength in the development of high velocity functional movements is questionable. It can be concluded that that is a point of diminishing returns as far as the continued increase of maximum strength is concerned in terms of its transfer to high velocity body weight movements.

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