South African Journal for Research in Sport, Physical Education and Recreation, 2010, 32(1):57-67.
Suid-Afrikaanse Tydskrif vir Navorsing in Sport, Liggaamlike Opvoedkunde en Ontspanning, 2010, 32(1):57-67.
ISSN: 0379-9069

BIOMECHANICAL, ANTHROPOMETRICAL AND PHYSICAL PROFILE OF ELITE UNIVERSITY NETBALL PLAYERS AND THE RELATIONSHIP TO MUSCULOSKELETAL INJURIES

Maryke A. FERREIRA & Emanuel J. SPAMER
School of Continuing Teacher Education, North-West University, Potchefstroom, Republic of South Africa

ABSTRACT

Literature indicates that deficiencies of certain parameters such as biomechanics, anthropometry, physical and motor abilities, may influence a netball players susceptibility to injury, as well as the players physical performance during a game. The primary aim of this study was to determine the physical profile of elite netball players from the North-West University club, between 18 and 25 years old, with reference to the biomechanical, anthropometrical, physical and motor abilities (balance, agility and explosive power). The secondary aim was to identify shortcomings in the physical profile of netball payers that could contribute to musculoskeletal injuries among players. The results reveal numerous biomechanical deviations among the netball payers during the first and second testing procedures. With regard to anthropometry, the group presented an ideal body mass index, but with an above-average fat percentage. A comparison of the incidences of injury among the players indicated that players with more biomechanical stressors showed more injuries during the season.

Key Words: Elite Netball Players; Biomechanical; Anthropometric; Physical; Profile; Musculoskeletal Injuries.

INTRODUCTION

Netball is a physically demanding game and is associated with traumatic and overuse injuries, and therefore associated with high injury incidences (Eggar, 1990; Hopper, 1986: 231-239). Literature indicates that deficiencies of certain parameters such as biomechanics, anthropometry and physical/motor abilities (agility, balance and explosive power) could influence a netball player’s susceptibility to injury, as well as the player’s physical performance during a game (Fuller & Drawer, 2004: 349-356; Rossouw & Rossouw, 2003: 52-54; Trojian & McKeag, 2006: 610-613). For the purpose of this study the definition by (Neely, 1998: 395-413) for biomechanics will be used, i.e. ”good biomechanics as near symmetry, good dynamic mobility and core stability of the human body”. It is therefore essential to identify these shortcomings prior to the start of the netball season by means of assessment procedures. Netball is played in South Africa on a regular basis in schools, clubs and at regional level. There are half a million netball players at school level in South Africa and 9700 adult players (Venter *et al.*, 2005: 3-7). Upon re-admission of South Africa in international sport in 1994 it became apparent that South African sports teams lacked specialised coaching, sport-specific skills, essential physique (i.e. body composition) and fitness skills that characterise elite sport (Venter *et al.*, 2005: 3-7). Optimal performance in netball relies on the interaction of several factors, including physical conditioning and technique. Venter *et al.* (2005: 3-7) emphasise that more comprehensive studies must be conducted to obtain normative data. Further research is not only essential to develop the game of netball at all levels in South Africa, but also to gain information in terms of injury rates and injury costs or financial implications. The primary aim of this study was to determine the physical profiles of elite netball players from the North-West University (NWU) Netball Club, aged between 18 and 23 years, with reference to the biomechanics, anthropometric measurements and physical/motor abilities (balance, agility and explosive power). The secondary aim was to identify shortcomings in the physical profiles (biomechanical variables, anthropometrical components and physical/motor abilities) of the netball players that could contribute to musculoskeletal injuries among these players. This study was the first attempt to provide normative data on provincial-level netball players at the North-West University.

METHOD

Elite female netball players from the first, second, third, fourth and the u/19 A and B teams of the North-West University Netball Club participated in this study. Elite players in this study refer to first team players at the different age groups at the North-West University. Forty players were tested during testing occasion one and twenty five players were tested during testing occasion two. A shortcoming in the method of this study was the fact that only 25 players were available for the testing occasion two. This was due to injuries and other dropout factors. The players were tested pre-season in March 2007 and post-season during August 2007. The biomechanical tests were conducted by applying an approach that measures a combination of symmetry, dynamic mobility and local stability of the body for the biomechanical assessment (Hattingh, 2003). This biomechanical assessment protocol evaluated different zones, namely limb-pelvic region, hip girdle, lower limb (knee and foot) and neurodynamics. Since literature reveals that these areas are the most susceptible to injury in Netball, the researchers decided to focus on these areas (Hass *et al.*, 2005: 100-107; Hattingh, 2003). Range of movement was graded as 1, 2 or 3. In most cases 1 means ideal, 2 non-ideal and 3 highly unsatisfactory. Detail for biomechanical analysis or deviations can be found in Ferreira (2007). For the anthropometric measurements, three standardised variables were used: body fat percentage by means of 6 skin fold measurements, stature by means of a tape measure, and body mass by means of a calibrated scale (Ross & Marfell-Jones, 1991: 223-308). Physical/motor abilities, including agility, balance and explosive power, were determined. The battery of tests used are: the Illinois agility run test (Kirby, 1991) for agility; the computerised balance test (Techno Therapy, 1992) for balance, and the vertical jump for explosive power, measured by means of a tape-switch sensory mat connected to a Psion organiser (Boscosystem Ergojump, 2007). A clinic, performed by physiotherapists, was held for injured players every Monday and this made it possible to monitor the injuries during the season. The clinic offered a diagnostic evaluation and advice, as well as a referral to a doctor or physiotherapist for treatment, when necessary. The definition for injuries, as described by Garraway and Macleod (1995: 1485-1487) was used in this study, i.e. an injury sustained on the field during a competitive match or during training, or during other active training directly playing or training from the time of injury or from the end of the match on training session in which the injury sustained. The injury report form that was completed include: mechanism of injury, diagnoses of injury, severity of injury, type of injury, time off from training, recommended treatment, revisit of player, etc. The training programme that was followed between test procedures 1 and 2, and that was conducted by an ex-national coach, concentrated on agility, balance, explosive power, pliometrics and speed endurance. Detail of the programme is available from the authors. A statistical analysis was done on all the data collected from the test batteries and injury clinics. Descriptive statistics (means, standard deviations, minimum and maximum values) were used as well as practically significant differences (d-values and p-values) (Ellis & Steyn, 2003: 51-53).

RESULTS AND DISCUSSION

TABLE 1: **CHANGES IN BIOMECHANICAL DATA FROM TEST ONE TO TEST TWO FOR THE TOTAL GROUP FOR SIGNIFICANT DIFFERENCES IN PERFORMANCE (N = 25)**

TEST VARIABLES	$\bar{x}_1$	$\bar{x}_2$	$\bar{x}_2 -$	Sd	p	d
BIOMECHANICS						
LOWER LIMB REGION:						
Achilles tendon suppleness test	1.2173	1.1304	-0.0869	-0.1689	0.4264	0.2061
Iliotibial band mobility test (ITB)	1.6251	1.8260	0.1739	0.3018	0.1618	0.3036
Quadriceps mobility	1.4347	1.7391	0.3043	0.5446	0.0159*	0.6004
Iliopsoas mobility	1.7826	1.7391	-0.0434	-0.0566	0.7883	0.0590
Gluteus maximus mobility test	1.4782	1.4347	-0.0434	-0.0773	0.7143	0.0733
Adductor mobility test	1.1304	1.0434	-0.0869	-0.3018	0.1618	0.2525
Internal rotation mobility test	1.0000	1.0000	0.0000	0.0000	-	0.0000
External rotation mobility test	1.5652	1.3043	-0.2608	-0.4823	0.0304*	0.4423
Q-angle test	1.1428	1.1428	0.0000	0.0000	-	0.0000
Patella squint test	1.1428	1.1428	0.0000	0.0000	-	0.0000
Patella tilt test	1.6666	1.6666	0.0000	0.0000	-	0.0000
Patella height test	1.9047	1.9047	0.0000	0.0000	-	0.0000
VMO – L comparison test	1.2380	1.2380	0.0000	0.0000	-	0.0000
Longitudinal arch status test	1.7619	1.7619	0.0000	0.0000	-	0.0000
Fore foot positional test	1.1904	1.1904	0.0000	0.0000	-	0.0000
Rear foot positional standing test	1.2857	1.2857	0.0000	0.0000	-	0.0000
Rear foot lying test	1.3333	1.3333	0.0000	0.0000	-	0.0000
Transverse arch area comparison test	2.0000	2.0000	0.0000	0.0000	-	0.0000
Foot mobility test	1.8095	1.8095	0.0000	0.0000	-	0.0000
Toe positional test	1.9047	1.9047	0.0000	0.0000	-	0.0000
PELVIC GIRDLE REGION:						
Leg length discrepancy test	1.7619	1.8095	0.0476	0.2182	0.3292	0.1091
ASIS comparison test	1.7619	1.8095	0.0476	0.2182	0.3292	1.1091*

PSIS comparison test	1.7619	1.8095	0.0476	0.2182	0.3292	1.1091*
Pelvic rami positional test	1.7619	1.8095	0.0476	0.2182	0.3292	1.1091*
Sacroiliac cleft test	1.0476	1.0476	0.0000	0.0000	-	0.0000
Bilateral pelvis positional test	1.8571	1.8571	0.0000	0.0000	-	0.0000
SPINAL REGION:						
Thoraco-lumbar fascia	1.2857	1.2380	-0.0476	-0.2182	0.3292	0.1028
Sacral rhythm test	1.0000	1.0000	0.0000	0.0000	-	0.0000
Functional extension mobility test	1.4285	1.2380	0.0952	0.1524	0.4929	0.2656
Functional flexion test	1.3333	1.4285	0.0952	0.1767	0.4275	0.1971
Rotational mobility test	1.4285	1.1428	0.0476	0.0956	0.6657	0.1583
Side flexion mobility test	1.0476	1.0000	-0.0476	-0.2182	0.3292	0.2182
Head positional	1.0000	1.0000	0.0000	0.0000	-	0.0000
Cervical	1.0000	1.0000	0.0000	0.0000	-	0.0000
Thoracic	1.1904	1.1904	0.0000	0.0000	-	0.0000
Lumbar	2.0000	1.9523	-0.0476	-0.1239	0.5763	0.1505
NEURODYNAMICS						
Straight leg raise (SLR)	1.2380	1.8095	0.5714	0.9561	0.0002*	1.3093*
Prone knee bend test (PKB)	1.2380	1.2380	0.0000	0.0000	-	0.0000

$d = \frac{|\bar{x}_1 - \bar{x}_2|}{s_{max}}$ = effect size for difference between means; a measurement of practical significance

$p \leq 0.05$ $d \geq 0.2$ (small effect)

$d \geq 0.5$ (medium effect) $d \geq 0.8$ (large effect)

$\bar{x}_1$ = mean value (test 1) * = Large significant *intra-group*

$\bar{x}_2$ = mean value (test 2) difference between testing episodes

Table 1 presents the comparison of the biomechanical results of the pre- (test one) and post-season testing occasion (test two) for the total group of elite NWU netball players. The reason for the comparison is to determine whether biomechanical changes occurred during the netball season. In the *lower limb region* only two practical significant differences ($p \leq 0.05$; $d \geq 0.8$) were identified. The first one was with the quadriceps mobility test ($p = 0.0159$), which indicated that the flexibility of the quadriceps for the total group decreased significantly during the season, with a medium effect size ($d = 0.6004$). The second practical significant difference ($p \leq 0.05$; $d \geq 0.8$) occurred with the external rotation mobility test ($p=0.0304$), which identified that the external rotation mobility improved during the course of the netball season, but the difference was small compared to the d-value of 0.4423.

In the *pelvic girdle region* high practically significant differences ($p \leq 0.05$; $d \geq 0.8$) were found in the ASIS comparison, PSIS comparison, and the pelvic rami positional tests. All three tests rendered the same value ($d = 1.1091$), which means that the asymmetries at the ASIS, PSIS and the pelvic ramis increased during the season. These pelvic asymmetries place more strain on the pelvic girdle of the players. No significant differences were identified in the *spinal region*. In the neurodynamics category, the SLR test found significant differences ($p = 0.0002$; $d = 1.3093$), which means that the *neurodynamics* of the players deteriorated during the season. In conclusion, only five significant biomechanical differences among the total group occurred during the season. The reason for this could be the fact that every netball player has a unique mechanical make-up due to structural characteristics, and in the absence of a specific conditioning programme concentrating to maintain the player's joint symmetry, flexibility, core stability and biomechanics will not alter during a season (Brukner & Khan, 2007). No other literature offered an explanation for these few biomechanical changes during the season. The practical significant differences which did occur were with regard to the quadriceps mobility; external mobility; ASIS comparison; PSIS comparison; and the pelvic rami positional tests.

TABLE 2: **CHANGES IN ANTHROPOMETRY AND PHYSICAL/MOTOR DATA FROM TEST ONE TO TEST TWO FOR THE TOTAL GROUP FOR SIGNIFICANT DIFFERENCES IN PERFORMANCE (N = 25)**

TEST VARIABLES	$\bar{x}_1$	$\bar{x}_2$	$\bar{x}_2 -$	Sd	p	d
ANTHROPOMETRY:						
Weight (kg)	68.2000	70.7200	2.5200	1.0209	0.00003*	0.2293
Height (m)	1.7460	1.7456	-0.0004	-0.0331	0.8697	0.0045
Body mass index (BMI)	22.3720	23.0720	0.7000	0.6052	0.0058*	0.3033
Fat percentage (%)	26.6172	27.5568	0.9396	0.4345	0.0399*	0.4372
SKINFOLDS:						
Tricep	16.9760	17.0120	0.0360	0.0102	0.9594	0.0104
Subscapular	11.6240	12.9560	1.3320	0.4261	0.0435*	0.5093
Supraspinal	14.1160	14.8640	0.7480	0.2303	0.2608	0.2191
Abdominal	20.8120	20.8560	0.0440	0.0110	0.9563	0.0143
Thigh	22.9920	29.0120	6.0200	1.0644	0.00001*	1.0644*
Calf	17.0240	15.7160	-1.3080	-0.4977	0.0201*	0.3973
PHYSICAL/MOTOR ABILITIES:						
Agility (sec)	19.4428	18.9476	-0.4952	-1.1890	0.00002*	0.7181
Balance (%)	69.3136	81.8681	12.5545	1.3027	0.000005*	1.0936*
Explosive power	33.7391	28.6087	-5.1304	-1.2851	0.000003*	1.0693*

$d = \frac{|\bar{x}_1 - \bar{x}_2|}{s_{max}}$ = effect size for difference between means; a measurement of practical significance

$p \leq 0.05$ $d \geq 0.2$ (small effect)

$d \geq 0.5$ (medium effect) $d \geq 0.8$ (large effect)

$\bar{x}_1$ = mean value (test 1) * = Large significant *intra-group*

$\bar{x}_2$ = mean value (test 2) difference between testing episodes

The *anthropometry* results are summarised in table 2. Significant differences occurred with regard to the weight, BMI, fat percentage, and subscapular, thigh and calf skinfold measurements. The weight of the total group (p = 0.00003) as well as the BMI (p = 0.0058) and fat percentage (p = 0.0399) increased significantly, although practical significant differences only indicated small effects ($d \geq 0.2$). Their subcutaneous fat increased practically significant especially in the subscapular ($p = 0.0435$), thigh ($p = 0.00001$; $d = 1.0644$) and calf ($p = 0.0201$) areas. Literature do not explain the increases in weight, BMI, fat percentage and skinfold measurements, but possible reasons for these increases could be, firstly, that the conditioning programme did not include adequate exercise routines during the season to increase their muscle mass and reduce their fat percentages, and secondly, that the second tests occurred three weeks into the players' off-season, meaning that for three weeks prior to the tests they did not train. Thus, significant increases occurred with regard to the weight, BMI, fat percentage, and the subscapular, thigh and calf skinfold measurements among the total group of netball players. No explanations for these increases could be found in literature. This occurrence could be an indication that the training program did not include adequate exercises during the season to improve muscle tissue and decrease body fat. Diet could also play a role; however, diet was not monitored as a parameter in this particular study.

The data of the *physical/motor abilities* for the total group is provided in table 2. Significant differences ($p \leq 0.05$; $d \geq 0.8$) were identified with all three motor tests (agility, balance and explosive power). The agility ($p = 0.00002$) and the balancing abilities ($p = 0.000005$; $d=1.0936$) of the total group improved significantly. However, a significant decrease in performance was identified with the explosive power test ($p = 0.000003$, $d = 1.0693$).

According to literature, the physical/motor abilities (agility, balance and explosive power) of a netball player could be enhanced during the netball season with the correct exercises (Baltaci & Kohl, 2003: 5-16; Clark & Burden, 2005: 181-187; Swanik & Swanik, 1999: 16-22; Verhagen *et al.*, 2004: 1385-1393). However, literature did not explain the decrease in performance with explosive power. One possible reason for the decrease in explosive power could be that the conditioning programme did not include adequate plyometric exercises to improve the netball players' explosive power.

TABLE 3: **DESCRIPTIVE STATISTICS OF INJURY EPIDEMIOLOGY AMONG THE TOTAL GROUP OF NETBALL PLAYERS (N = 25)**

Injury incidence	**%**
1. Severity of injury:	
Grade I	34.78
Grade II	56.52
Grade III	8.69
2. Body part:	
Ankle	39.13
Knee	28.26
Cervical	8.69
3. Mechanism of injury:	
Incorrect landing	52.17
No incident	34.78
Fall incident	4.34

The secondary aim of this study was to identify the shortcomings of the physical profiles (biomechanical variables, anthropometrical components and motor abilities) of the netball players that could contribute to musculoskeletal injuries. The study also explored the occurrence of injuries, the mostly affected body parts, as well as the mechanisms of injuries.

The statistics on injuries are discussed under three sections, namely the severity of the injury (grade of injury); the body part mostly affected; and the mechanism of injury (see table 3). Of the 46 injuries that occurred during the season, 34.78% were classified as Grade I (minor) injuries, while 56.52% were categorised as Grade II (moderately serious) and 8.69% as Grade III (serious) injuries (Van Mechelen *et al.*, 1992: 82-99). The majority of these injuries were classified as moderately serious, meaning that the injured players were unable to return to netball (training and games) for 8-21 days.

The body parts mostly affected by injuries were the ankle joint (39.13%), followed by the knee joint (28.26%) and thirdly the cervical region (8.69%). Similar findings were found in literature, i.e. the joints mostly affected by traumatic injuries in netball are the ankle and knee joint. In a study conducted by Hopper (1986: 231-239) on Australian netball players, the incidence of injury revealed that 58.2% of injuries occurred at the ankle; 15.2% at the knee; 13.3% at the hand and 13.3% at other parts of the body. A study conducted by Steele (1990: 88-102) on lower limb and back injury patterns of elite netball players reported 30.2% ankle injuries, followed by 15.9% shin/calf injuries. These findings were similar to the results of a one day veterans' netball tournament, where 29.6% of players presented with ankle injuries and 13.6% complained of leg/calf problems (Steele, 1990: 88-102). According to Hopper (1986: 231-239) the ankle, knee and hand are the most common sites to be injured. Various studies conclude that statistically the ankle and knee joints are the most susceptible to injury (Hopper *et al.*, 1995a; Trojian & McKeag, 2006: 610-613).

The most common mechanism of injury was incorrect landing technique (52.17%). A fall incident was reported as the mechanism of injury with 4.34% of the injuries. The existing literature correlated with these data. Incorrect landing (73.8%), a slip or a fall (74.2%) was the main causes of injuries with a study conducted by Hopper (1986). A similar incidence of perceived reason for injury was recorded for contact with another player (29%), and incorrect landing (29%) followed by a slip, trip or sudden stop (21%) (Hopper *et al.*, 1995b: 223-228). With some of the injuries (34.78%), the players could not report a specific traumatic incident that caused the injury, meaning that the origin of these injuries could be due to overuse. The existing literature correlates with these data. Overuse injuries are defined as injuries to a body part of an athlete or individual where no trauma was involved (Brukner & Khan, 2007).

Incorrect biomechanics is considered as a potential cause of overuse injuries (Arnheim & Prentice, 2008; Bell-Jenje & Bourne, 2003; Brukner & Khan, 2007; Fuller & Drawer, 2004: 349-356; Hopper & Elliot, 1993: 148-162; Kendall *et al.*, 1993; Rossouw & Rossouw, 2003: 52-54). Hopper and Elliot (1993: 148-162) conducted a study on the relations between lower limb and back injuries with perceived landing patterns and podiatric variables for injured and uninjured elite netball players. More than 25% of the 240 participants in that study had overuse type injuries. These injuries involved retropatellar pain (24%) and shin pain (38%) (Hopper & Elliot, 1993: 148-162). Ninety two percent of the 228 participants were given a podiatric assessment. The study found that 22.5% of the players were cleared as "normal" and an astonishing 42.1% of the players presented with rear foot varus with compensating subtalar pronation. Excessive pronation may produce an unstable forefoot; therefore the netball player could be susceptible to an ankle sprain (Donatelli, 1990). Interestingly, during this study the pre-season testing procedure identified that 74% and 69% of the participants presented with rear foot pronation with the rear foot standing and lying tests respectively. With the post-seasonal tests, of this study, this tendency (rear foot pronation) occurred in 80% and 76% of the participants with the same tests (rear foot standing and lying tests). In other words, a large number of the netball players presented with rear foot pronation, which is considered a biomechanical deviation. Rear foot pronation could contribute to the occurrence of overuse injuries such as sesamoiditis; plantar fasciitis; Achilles tendinopathy; Peroneal tendinopathy; medial shin pain; patellar tendinopathy; patellofemoral syndrome; metatarsal stress fracture and navicular stress fracture. This biomechanical stressor (rear foot pronation) could have been the cause of a number of the overuse injuries which occurred during the season among the netball players participating in this study. These overuse injuries included injuries such as, patellofemoral syndrome; medial shin pain; groin and popliteus strains; lumbar facet joint impactions; and navicular ligament strain.

To conclude, the NWU club elite netball players showed a higher injury incidence than previous studies on netball injuries. A relation may exist between the high injury incidence and the numerous biomechanical deviations, poor anthropometry and inadequate motor abilities (average agility and balance and unacceptable explosive power) which were detected among these players. Most of the recorded injuries were moderately serious injuries, while the body part mostly affected was the ankle joint, with incorrect landing technique as the most common mechanism of injury.

CONCLUSIONS AND RECOMMENDATIONS

The physical profiles of club netball players from the NWU (aged between 18 and 23 years) with reference to their biomechanics, anthropometric measurements and physical/motor abilities (agility, balance and explosive power) were documented in order to address the primary aim of this study. Shortcomings in the physical profile of netball players that may contribute to musculoskeletal injuries were also investigated. Reasons for the high injury rate among the total group may be the results of biomechanical deviations, as well as poor anthropometry and relatively average physical/motor abilities. The average BMI of the group was considered ideal, with an unacceptable above-average fat percentage. The total group reported average agility and explosive power abilities for the physical/motor tests during the first testing occasion, but with poor balance. During the second testing occasion, the averages for agility and balance were considered acceptable, but the explosive power abilities were below average. These inadequate physical/motor abilities may have contributed to the netball players' injuries. Alterations or shortcomings with regard to any of these parameters (biomechanics, anthropometry and physical/motor abilities) could make netball players more susceptible to traumatic and overuse injuries. It can thus be concluded that Netball players with more biomechanical deviations sustain more injuries. Shortcomings in the netball players' physical profile (biomechanical, anthropometry and physical/motor abilities), that may have contributed to the occurrences of musculoskeletal injuries, were identified.

It is recommended that prior to and during the netball season, coaches should facilitate "screening" procedures during which the physical profile of every netball player is determined. This should involve a biomechanical analysis, anthropometrical assessment and physical/motor tests (agility, balance and explosive power). The multidisciplinary team should apply testing protocols to address their needs; they could apply the same tests performed in this study, or use tests from other applicable studies (Elphinston & Hardman, 2006: 169-176; Venter *et al.*, 2005: 3-7; Young *et al.*, 2002: 282-288). These "screening" procedures should include parameters which are essential for a netball player to perform best during a game and to decrease her probability for injuries. The results of these "screening" procedures may also be compared to the data of this study.

The main shortcoming of this study is that the post-season testing of many players did not realise due to unforeseen circumstances. This negatively affected the data of the second testing occasion. The participation of an identical group in testing procedures one and two could have presented more reliable results. More attention should be paid to the communication between researchers, individual coaches and players regarding test dates and player commitment. However, the physical profile that was presented after tests procedures can be used by coaches as a norm for the profile of talented netball players as tested in this study. On the other hand, the results of test procedure 2 give a good indication of what has happened to the physical profile of players during the season, as well as the effect of injuries, despite the decrease in numbers that was tested.

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Prof. Emanuel J. Spamer: School of Continuing Teacher Education, North-West University, Private Bag X6001, Potchefstroom 2531, Republic of South Africa. Tel.: +27 (0)18 299 4556, Fax.: +27 (0)18 299 4558, E-mail: manie.spamer@nwu.ac.za

(Subject editor: Dr. R.E. Venter)