PERFORMANCE CAPABILITIES OF SWIMMERS WITH A DISABILITY

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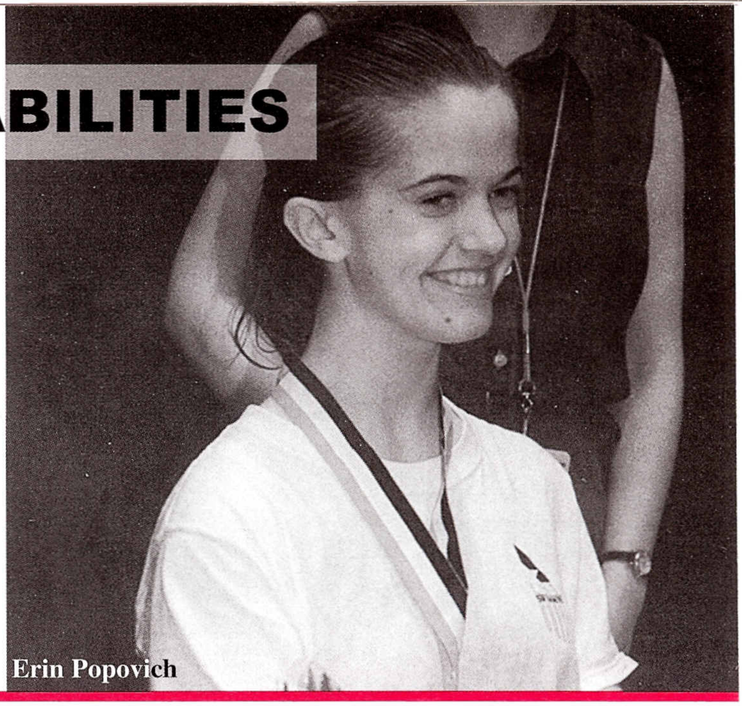

Erin Popovich

In the September 2000 issue of National Geographic, Jason Wening was asked "Why do you do it?" Wening, a bilateral below-knee amputee swimmer, answered, "For the simple pleasure of forcing the body and mind I was given to the absolute edge of my capabilities. I'm fascinated by trying to go ever faster. And when I do, I get for just a moment a vision of the limitless potential of the human race."

Like Jason, we were curious about the performance capabilities of swimmers with a disability, and we believed that coaches could use such data to help establish performance goals for swimmers with a disability. We had the opportunity to test two of America's top swimmers, Jason Wening and Erin Popovich, at the International Center on Aquatic Research in July 2000. This article includes data on body size, physiological conditioning, stroke technique, and use of psychological strategies for these athletes.

Bios

Jason Wening, age 26, has bilateral below-knee amputations, a missing radius bone in the left forearm, and a partial amputation of the left hand. Jason is a veteran of the Barcelona, Atlanta, and Sydney Paralympic Games. For the past few years, during his preparation for the Sydney Games, he has been a member of the Ann Arbor Swim Club (MI) coached by Shawn Kornoelje. He "owns" the distance freestyle events for his classification, with world records in the Class S8 400m (4:42.97), 800m (9:42.87), and 1500m (18:39.88) freestyle events. Jason established new world marks in the 400m freestyle three times this year, during finals at the USA Swimming Disability Championships in June, and during both the preliminary and finals heats at the Sydney Paralympic Games. Jason also competes in "able-bodied" open water events, most recently in the USA Swimming 5K Open Water Championships in Indianapolis, where he placed 27th of 33 swimmers with a time of 1:01:44. He won the 25-29 age group and was 5th overall at the U.S. Masters Swimming 5K National Championships with a time of 1:05:50.

Erin Popovich, age 15, has achondroplasia, a form of dwarfism characterized by short arms and legs. She swims for the Butte Tarpons Swim Team (MT) where she is coached by Bill Seaver and Marie Cook. Erin qualified for her first Paralympic Games this year. Erin established four new world records for her classification at the Sydney Games – in the Class S6 100m free (1:19.72), Class SB5 100m brst (1:45.93), Class S6 50m fly (39.13), and Class SM6 200m IM (3:19.87). She was America's top medal winner in any sport with three gold and three silver medals. Her accomplishments were rewarded by her selection as the USA flag-bearer for the closing ceremonies.

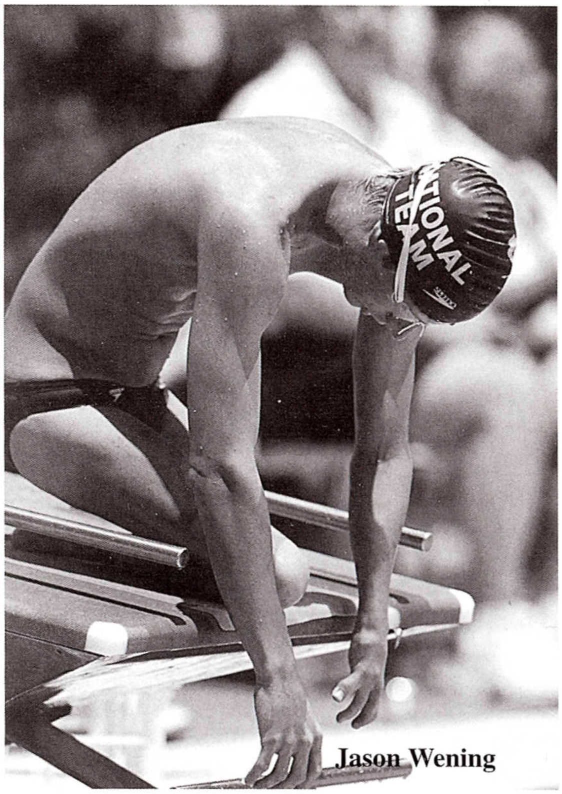
Body Size Characteristics

Height, weight, and arm span were measured using standard anthropometry techniques (Lohman, Roche, & Matorell, 1988). The data in Table 1 reflect Jason's actual measured height, as well as projected height if his leg length were proportional to his sitting height. Percent fat was assessed using the Siri equation (Siri, 1961) using the triceps, subscapular, chest, midaxillary, suprailiac, abdominal, and thigh skinfolds.

Table 1. Anthropometric Characteristics

	Height (cm)	Weight (kg)	Percent fat	Arm span (cm)
Jason Wening	152.4 actual 174.0 projected	45.45	6.9	173.0
Erin Popovich	127.0	43.18	21.7	131.0

The anthropometric data reveal that Jason has a very lean, athletic body type, while Erin's body composition is in the average range for adolescent girls. Although the Siri percent fat formula was not designed for people with amputations or dwarfism, the values obtained for Jason and Erin seem reasonable in the judgment of the Sport Science staff members who conducted the testing. Readers should take note of the height and arm span measures. Short stature (for Jason because of leg amputations and for Erin because of dwarfism) probably has a negative influence on drag given that longer, leaner shapes typically have less drag. Although Erin's short arms and legs limit her ability to generate propulsion, she does have a relatively long arm span for her standing height that undoubtedly contributes to her success in swimming.



Jason Wening

Physiological Conditioning

Physiological measures included an oxygen consumption (VO2) test and a lactate/heart rate profile (Battista & Margarucci, 2000). The test consisted of a discontinuous incremental swim in the flume consisting of 2-min stages followed by 1-min rest periods until the athlete could no longer keep up with the velocity. Water speed (m/sec) was based upon the swimmer's best recent 200m freestyle time, 2:20 for Jason and 3:00 for Erin. During the swim portion of each stage, a mask with a two-way non-rebreathing mouthpiece was worn. Expired gases were collected from this mouthpiece and analyzed for determination of VO2. During the rest portion of each stage, heart rates (HR) were recorded using a HR monitor, and blood lactates (LA) were obtained from an ear stick and analyzed in a Lactate Pro machine. Stroke rates (SR) were taken after the first minute of each swim stage to allow the swimmer to adjust to the water velocity. A recovery heart rate was recorded at 1 min following the last stage. Passive recovery LA measures were taken for Jason at 3 min, 13 min, and 23 min following the last stage, but not for Erin.

Table 2. Results of Maximum Oxygen Consumption Test

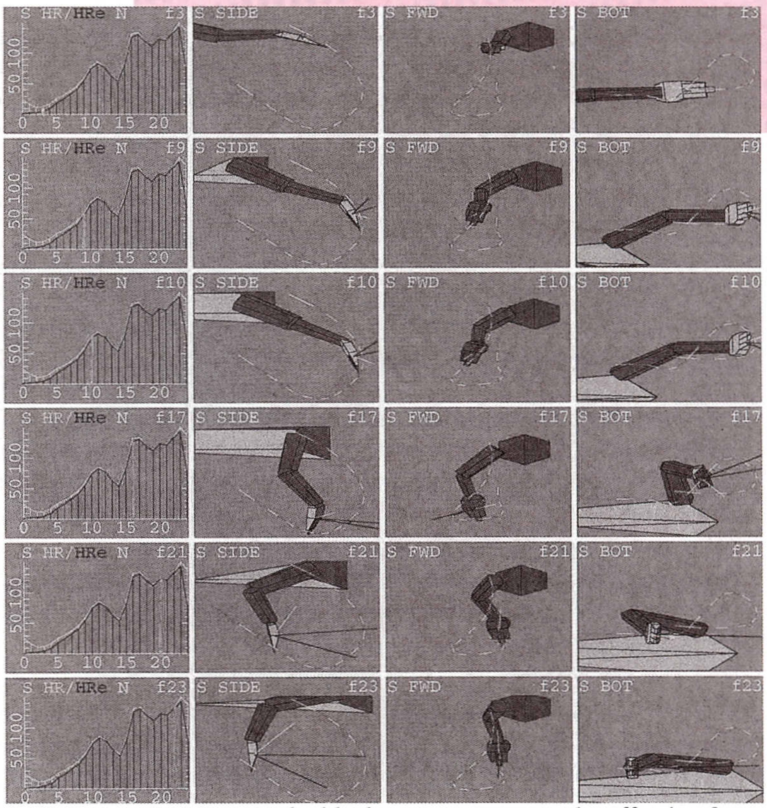
	Speed (% of recent 200m time)	**Velocity** (m/s)	**Heart Rate** (bpm)	**Lactate** (mmol/l)	**VO2** (ml/kg/min)	**Stroke Rate** (cycles/min)
Jason Wening						
Stage 1	75	1.08	84	1.2	36.80	38.5
Stage 2	80	1.15	90	1.1	40.50	38.5
Stage 3	85	1.22	96	1.7	50.18	38.5
Stage 4	95	1.37	144	2.8	60.37	45.0
Stage 5	100	1.44	156	4.3	67.50	47.0
Stage 6	100+	1.52	186	7.3	75.47	49.0
Recovery:						
1 min			108			
3 min				7.3		
13 min				3.7		
23 min				1.4		
Erin Popovich						
Stage 1	80		136	1.9	35.59	38.5
Stage 2	90		158	3.4	43.17	42.5
Stage 3	100		188	6.6	48.44	46.0
Stage 4	100+		198	10.3	50.49	50.0
Recovery:						
1 min			164			

Coaches should use caution when interpreting the results presented in Table 2. First, the results of a VO2 max test while swimming cannot be compared directly to the results of treadmill or cycling protocols, because swimming imposes different stresses on the body, such as a horizontal body position and water resistance. For example, elite level athletes can achieve VO2 max values from 65 to 75 ml/kg/min in running and cycling protocols, while data from USA Swimming Sport Science show elite swimmers from the 1990 National Team with values from 55 to 65 ml/kg/min. Next, swimming VO2 max tests depend a lot on skill rather than just pure aerobic ability (Brooks, Fahey, White, & Baldwin, 2000). Efficiency is affected by exercise intensity, stroke mechanics (which can break down at faster paces), and body shape. Finally, we must consider individual differences due to disability, age, and gender.

Jason demonstrated a typical response to a graded exercise tolerance test. As the water velocity was increased from 1.08 m/s to 1.52 m/s, his VO2, HR, LA, and SR values all increased as expected. His HR dropped 78 beats per min during the first minute of recovery following the test, and his LA value 23 min after the test had returned to a near starting value, demonstrating excellent aerobic conditioning typical of an endurance athlete. Despite his disability and obvious lack of power from his legs, Jason achieved a very high peak VO2 (75.47 ml/kg/min). Efficient stroke technique (described later in this article) undoubtedly helps Jason to achieve higher aerobic efficiency than many able-bodied swimmers.

Erin also demonstrated a typical response to the graded exercise test in the flume, with VO2, HR, LA, and SR values increasing as a function of faster water velocities. Her HR dropped 34 beats per min during the first minute of recovery following the test. Erin's peak VO2 value of 50.49 ml/kg/min may have been affected by several factors. This is a relatively high value for her age and gender; however, VO2 is trainable for adolescents (Brooks, et al., 2000), so Erin still has much room for improvement in the years to come. Also, because her arms and legs are short, Erin has less muscle mass in her limbs than "able-bodied" people of the same stature. This limited muscle mass is probably associated with lower oxygen consumption. Like Jason, Erin's mechanical efficiency probably contributed to her relatively high peak VO2. The stroke rate data provide evidence of her efficiency. Dwarf swimmers typically have low distance per stroke because short arms limit propulsion, and they tend to compensate for low distance per stroke with high stroke rates. However, Erin's stroke rates ranged from 38.5 to 50.0 cycles/min in comparison to mean race-pace stroke rates of 56.2 cycles/min (SD=6.7) for 7 elite swimmers with achondroplasia tested at camps at the Olympic Training Center (Dummer & Heusner, 1996).

Figure 1. Stroke Technique of Jason Wening – Freestyle Right Arm. The four panels show the force curve and views from the side, front and bottom.

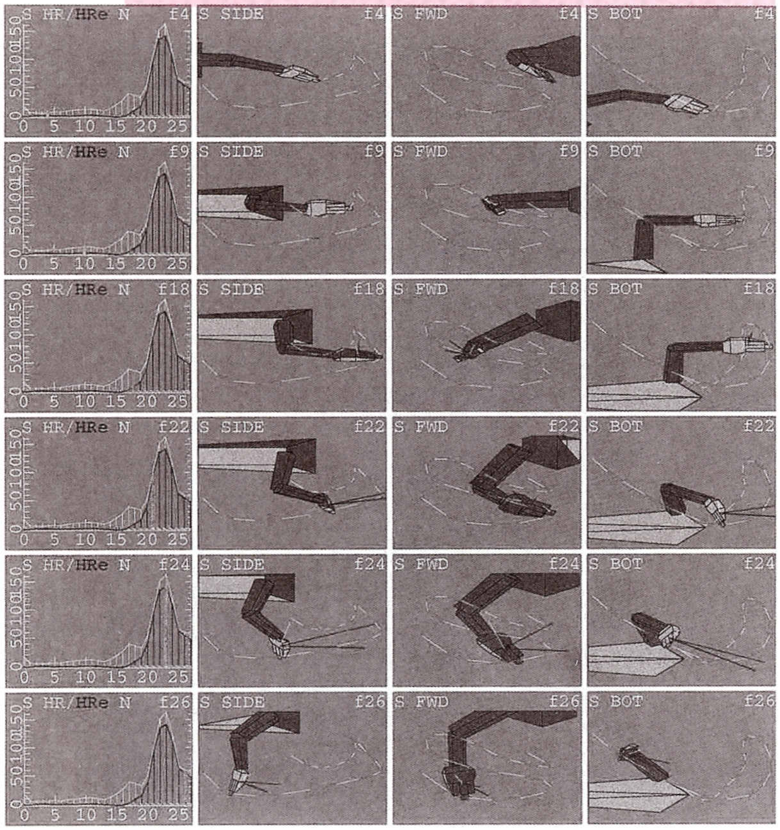


Stroke Technique

Each swimmer had an opportunity to swim in the flume and have one of their strokes digitized. Jason had his freestyle arm pull digitized, at a pace of 1:05 for 100 meters, and Erin had her butterfly pull digitized, swimming at a pace 1:40 for 100 meters. Figures 1 and 2 provide a series of "snapshots" for Jason and Erin at selected points in their strokes. In each "snapshot" we see an estimate of the force the swimmer is producing in the first panel (left graph). In the force profile, two curves are plotted. The white curve represents the total force generated by the athlete, regardless of the direction the force is being directed, and the black curve represents the effective force, or the amount of the total force that is being used for propulsion. In an ideal world, these two curves would lie one on top of the other, signifying that all of the generated force is used for propulsion. That is impossible, however, due to the way the body is designed, especially at the catch phase of the strokes. We like to see those curves come together though, as the stroke cycle progresses. The remaining three panels show the hand and arm position from different points of view: from the side (panel 2), from the front (panel 3) and as if you were looking at them from the bottom of the pool (panel 4). In each camera view, we can also see the complete pull pattern, denoted by the dashed line. Due to space restrictions, only one side of the athlete's pull pattern is shown.

Jason is extremely effective in generating propulsive force during the freestyle arm pull. The catch is initiated by a break in the wrist, followed by a bend at the elbow. Jason's elbow remains relatively high throughout the stroke cycle, and much of the force he generates is effective at propelling him down the pool. The force trace is also a good indicator of hand acceleration, and we

Figure 2. Stroke Technique of Erin Popovich – Freestyle Right Arm. The four panels show the force curve and views from the side, front and bottom.



can see that Jason continues to accelerate his hand throughout the pull (with the exception of a small dip during the insweep). The pulling patterns also tend to resemble what we see in some of the more efficient able-bodied athletes; there is a slight sculling action, but for the most part, water is pushed towards the feet. This is remarkable, since Jason is swimming without propulsion from his legs. In able-bodied athletes, the legs serve as a stabilizing mechanism, allowing the upper body to perform movements that might normally throw it out of line. The fact that Jason has "normal" pulling patterns and is able to generate propulsion efficiently without much use of his legs suggests that he has tremendous strength in his core, and focuses on technique while taking into account his physical limitations.

Erin tends to show some deviations in technique in comparison to the most efficient able-bodied butterfliers. However, these alterations are most likely adaptations to her physical limitations, and help to make her as efficient as she can be. Erin tends to scull a great deal, and does not really "push" the water. While this would deviate from optimal technique for able-bodied swimmers, the likely explanation is that the sculling movements help to lengthen her stroke to compensate for her shorter arms. Erin maintains a fairly high elbow and has good arm position through the propulsive portion of her stroke. While Erin probably could make her catch phase a bit shorter and her catch and finish phases slightly more efficient, her overall stroke mechanics, like Jason's, are effective and specifically adapted to her own body.

The take home messages for coaches with regards to stroke mechanics are:

- Athletes with a disability are capable of swimming with "near-normal" stroke technique. However, as with able-bodied athletes, some of the fine points of technique must be modified to suit the individual athlete. Keep these limitations in mind, but do not let them keep you from challenging the athlete to achieve perfection.
- Do not be afraid of asking the athlete to experiment with some different stroke ideas. Again, treat them just like any other swimmer. Have them "tweak" their mechanics here and there, and note the effects, to find what works best for them. Some techniques will improve performance and some will not.

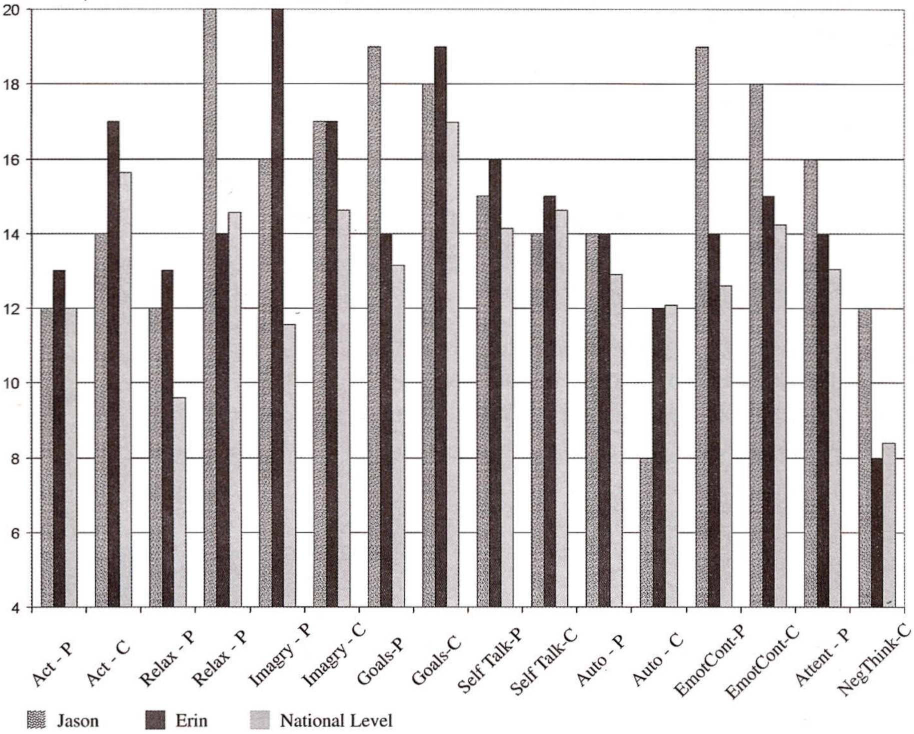
Mental Training

Each swimmer completed the Test of Performance Strategies (TOPS), an inventory used to measure the extent to which an athlete uses specific psychological skills in both practice and competition. The following skills (mental skills that are purported to influence performance) are measured in the TOPS:

- Activation – Raising psychological energy. Psyching-up.
- Relaxation – Lowering somatic anxiety. Lowering high levels of physiological arousal.
- Imagery – Creating or recreating an athletic experience in your mind. Also referred to as visualization.
- Goal Setting – Setting goals and adhering to a goal-setting program over time.
- Self Talk – Speaking to yourself positively during practice and competitions.
- Automaticity – Performing with minimal conscious cognitive control. Also called "autonomous," "automatic," or "being in flow."
- Emotional Control – Coping with frustration and negative emotions.
- Attentional Control (practice skill) – Maintaining focus and attention on relevant cues.
- Negative Thinking (competition skill - lower scores are better) – Focusing on mistakes, problems, or negative situations during competitions.

Figure 3 depicts the extent to which Jason and Erin reported using psychological skills in practice (P) and competition (C) relative to the average scores reported by national-level able-bodied swimmers in USA Swimming. Note that the range for each skill is 4 to 20 points with 20 points indicating extensive use of the skill.

Figure 3: Test of Performance Strategies



Like the national-level able-bodied swimmers, Jason and Erin both make extensive use of the psychological skills in both practice and competition, suggesting, in part, that they are taking steps to manage and facilitate their performances in practice and competition. The fact that Jason and Erin both made more extensive use of sport psychology techniques than a group of 39 swimmers with a disability who participated in a training camp at the U.S. Olympic Training Center in 1995 (Fitzpatrick, Dummer, Ewing, & Colón, 1996) suggests that other swimmers with a disability could benefit from training in mental skills.

Another psychological inventory was administered to the athletes to measure tendencies for task and ego involvement in sport. Scores on this test range from a minimum of 0 to a maximum of 5 points. Athletes with a strong task orientation typically focus on self improvement and the process of performance. Athletes with a strong ego orientation tend to focus on performance relative to others and a concern with outcome. Research suggests that a task orientation (compared to an ego orientation) will lead to a strong work ethic, persistence, and optimal performance. Jason and Erin scored moderately high in

Table 3. Task and Ego Involvement in Sport

	Task Orientation	Ego Orientation
Jason Wening	3.14	3.67
Erin Popovich	4.57	4.33
Olympic Trials Participants	4.16	3.32
Norms	4.08	2.87

both the task and ego orientation. The same trend was found in research on Olympic Trials qualifiers. It seems that while the athletes (both Jason and Erin and Olympic Trials Qualifiers) have a moderately strong tendencies to focus on their own performance, winning and concern over outcome is equally salient.

Conclusion

The findings presented in this article are intended to help coaches of swimmers with a disability to recognize the possibilities for excellence in athletic performance. If coaches continue to "raise the bar" by challenging swimmers with a disability to achieve high levels of physical conditioning, excellent stroke technique, and effective use of psychological strategies, we will witness a continued assault on the record book and improved success for USA teams in international competitions.

References

Battista, R., & Margarucci, C. (2000). ICAR physiological testing profiles. Coaches Quarterly, 6(1), 20-22.

Brooks, G. A., Fahey, T. D., White, T. P., & Baldwin, K. M. (2000). Exercise physiology: Human bioenergetics and its applications. Mountain View, CA: Mayfield.

Dummer, G. M., & Heusner, W. J. (1996, September). Stroke technique characteristics of elite swimmers with disabilities. Paper presented at the North American Federation of Adapted Physical Activity, Banff, Alberta, Canada.

Fitzpatrick, J. M., Dummer, G. M., Ewing, M. E., & Colón, G. (1996, September). Use of sport psychology techniques by elite swimmers with disabilities. Paper presented at the North American Federation of Adapted Physical Activity, Banff, Alberta, Canada.

Gore, R. (2000). What it takes to build the unbeatable body: Pushing the limits. National Geographic, 198(3), 2-33.

Lohman, T. G., Roche, A. F., & Martorell, R. (1988). Anthropometric standardization reference manual. Champaign, IL: Human Kinetics.

Siri, W. E. (1961). Body composition from fluid space and density. In J. Brozek & A. Hanschel (Eds.), Techniques for measuring body composition. Washington, DC: National Academy of Science.

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