BIOMECHANICS OF TRIPLE JUMP

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Scientific Service and Research

- Started in 1982 for preparation of 1984 Los Angels Olympic Games
- Supported by Science and Technology Committee of USOC and Sports Medicine and Science Committee of USA Track & Field
- University scientific service and research partners

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Scientific Service and Research

- Current team
  - 8 PhD in biomechanics
  - 10 PhD in physiology
  - 15 PhD in psychology
  - 4 PhD in nutrition

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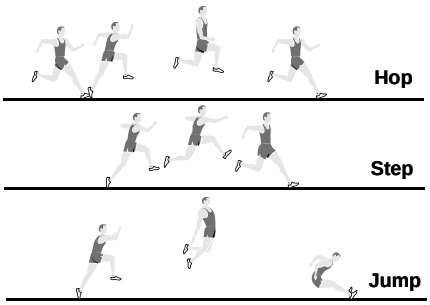
Triple Jump



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Triple Jump

- One of the three most technically and physically demanding events in track and field
  - Multiple efforts at high speed (technically demanding)
  - Great ground reaction force (physically demanding)

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Biomechanical Studies

- Biomechanical studies on triple jump techniques
  - Many qualitative analyses of triple jump techniques for individual athletes
  - Not many systematic scientific studies
  - Biomechanical studies on triple jump techniques at University of Iowa from 1982-1996

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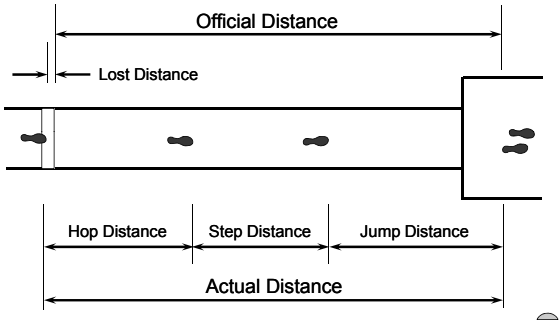
Biomechanical Studies

- Systematical biomechanical studies on triple jump techniques at University of Iowa
  - Lead by Dr. James G. Hay
  - Part of the Scientific Service Program for horizontal jumping events in USA Track & Field
  - Studies on triple jump from 1988 to 1996

Studies on Triple Jump

- Approach run
- Optimum phase ratio
- Functions of arm swing motions in the triple jump

Distances in Triple Jump



Official and Actual Distances

- Actual distance = Hop distance + Step distance + Jump distance
- Official distance = Actual distance – lost distance

Approach Run

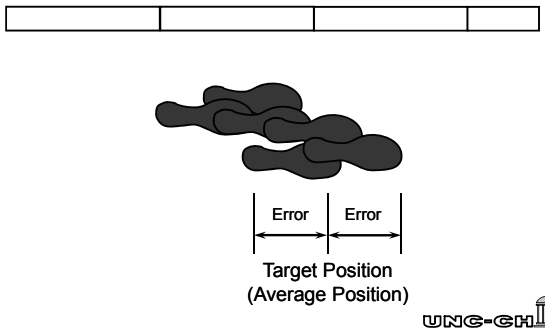
Approach Run

- An very important part of the triple jump
  - The beginning of the triple jump
  - Ensure a legal trial
  - Obtain horizontal speed for the triple jump

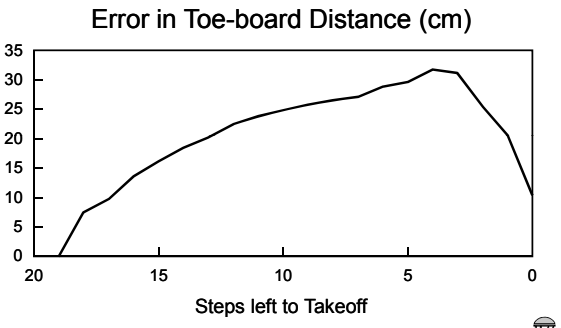
Approach Run

- Requirement to approach run in triple jump and long jump
  - Accuracy
  - Speed

Position Error in Approach Run



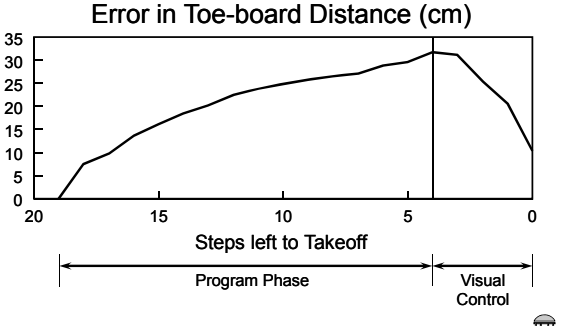
Position Error in Approach Run



Position Errors in Approach Run

- Run straight forward without visual feedback
- Take visual feedback
- Make adjustment to position

Phases in Approach Run



Evaluation of Approach Run

- Program phase
  - Maximum error in toe-board distance
- Visual control phase
  - Error in toe-board distance at the takeoff
  - Percentage of legal trials
  - Correlation between adjustment of toe-board distance and speed

Evaluation of Approach Run

- Maximum error in toe-board distance
  - Reflects the accuracy of approach run in program phase
  - Maximum error in stride length can be used to determine which strides are the major contributors to maximum error in toe-board distance

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Evaluation of Approach Run

- Toe-board distance at the takeoff
  - Reflect the overall accuracy of approach run
  - Reflect the effort of adjustment to toe-board distance in visual control phase

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Evaluation of Approach Run

- Percentage of legal trials
  - Reflect the nature of the toe-board distance at the takeoff
  - An indication of adjustment of starting position
  - An indication of the accuracy of visual control

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Evaluation of Approach Run

- Correlation between adjustment in toe-board distance during visual control phase and horizontal speed at the beginning of takeoff
  - A measure of the ability to adjust toe-board distance without reducing speed

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Evaluation of Approach Run

- Development of approach run score system
- Development of training methods for approach run
- Development of Computer Expert System of evaluation of approach run

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Approach Run Training

- Program phase
  - Approach run with different wind speed
  - Approach run with mini hurdles
- Visual control phase
  - Approach run with altered starting position

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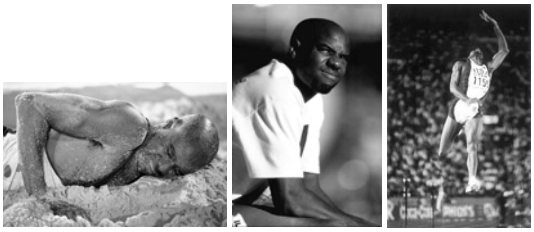
Application of Research Results

- 1991 Mike Powell's world record long jump



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Application of Research Results

- The results of our research on approach run can also be applied to high jump, pole vault, and javelin throw

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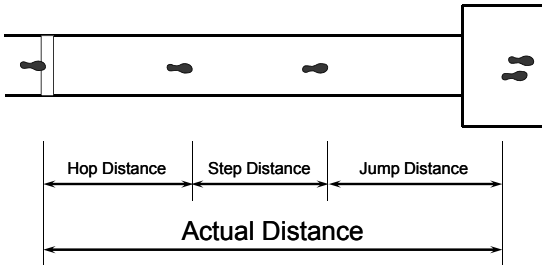
Optimum Phase Ratio

Optimum Phase Ratio



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Optimum Phase Ratio

- Phase percentage = The percentage ratio of a phase distance to the actual distance
- Phase ratio = The ratio of the three phase percentages

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Optimum Phase Ratio

- Hop = 6.00 m, step = 4.80 m, jump = 6.80 m, actual distance = 17.60 m
- Hop percentage = 34, step percentage = 27, jump percentage = 39
- Phase ratio = 34 : 27 : 39

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Optimum Phase Ratio

- A measure of effort distribution
- An important consideration of triple jump techniques
  - Effort distribution decides jumping techniques in different phases, especially in the hop and step phases

(Hay, 1992)

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Optimum Phase Ratio

- Three commonly used triple jump techniques in terms of phase ratio
  - Hop-dominated technique (High hop)
  - Jump-dominated technique (Flat hop)
  - Balanced technique

(Hay, 1992)

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Optimum Phase Ratio

- Hop-dominated or balance techniques for world records before 1972
- Jump-dominated techniques for the last three world records

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Optimum Phase Ratio

- 1972, Victor Saneyev, 17.44 m, the last world record with hop-dominated technique
- 1975, Joao Carlos de Oliveira, 17.89 m, the first world record with jump-dominated technique, the largest improvement of world record

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Optimum Phase Ratio

- 1985, Willie Banks, 17.97 m, jump-dominated technique
- 1995, Jonathan Edwards, 18.29 m, jump-dominated technique

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Optimum Phase Ratio

- Research questions
  - Is there an optimum phase ratio for a given athlete?
  - How to determine the optimum phase ratio for a given athlete?

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Optimum Phase Ratio

- Research Questions
  - Is there any relationship between the loss in the horizontal velocity and the gain in the vertical velocity during each support phase?
  - Is this relationship the same for all triple jumpers?

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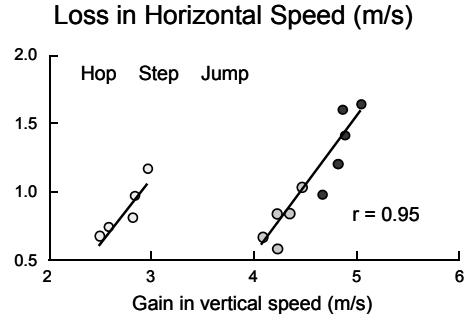
Optimum Phase Ratio



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Optimum Phase Ratio

- Velocity conversion coefficient (A_1)
  - The slope of the linear relationship between the gain in vertical velocity and the lose in horizontal velocity
  - Significant effect on the efficiency of each jump in triple jump

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Optimum Phase Ratio

- Actual price for the gain in vertical speed

$$\lambda = \frac{\text{Loss in horizontal Speed}}{\text{Gain in Vertical Speed}}$$

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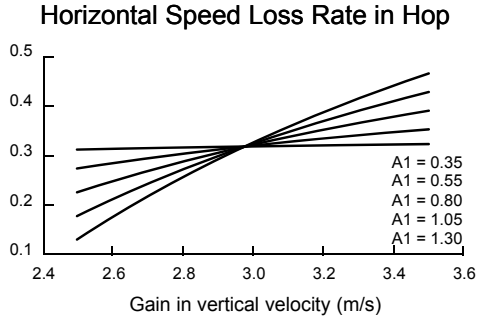
Optimum Phase Ratio



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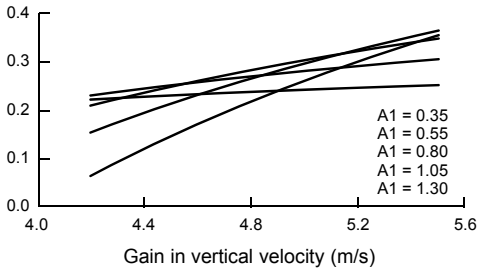
Optimum Phase Ratio



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Optimum Phase Ratio

- Applications
  - A biomechanical model for optimum phase ratio for individual athletes
  - Actual distance as a function of velocity conversion coefficient and gains in the vertical velocity during three support phases

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Optimum Phase Ratio

- Optimum techniques
  - Jump-dominated technique for $A_1 \geq 0.9$
  - Jump-dominated or balanced technique for $0.9 > A_1 > 0.5$
  - Balanced or hop-dominated technique for $A_1 \leq 0.5$

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Optimum Phase Ratio

- Significant effect of approach run velocity on the optimum phase ratio for $0.9 > A_1 > 0.5$

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Optimum Phase Ratio

- Answers to research questions
  - There is not a single optimum phase ratio for all triple jumpers
  - Optimum phase ratio is different from athlete to athlete
  - Velocity conversion coefficient is the determinant of optimum phase ratio

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Effects of Optimum Phase Ratio

- Research questions
  - How phase ratio affects the actual distance?
  - With phase ratio optimized, how other biomechanical factors affect the actual distance?

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Effects of Optimum Phase Ratio

- Biomechanical Model
  - Input = velocity conversion coefficient, approach run velocity, takeoff and touchdown heights and distances
  - Output = actual distance with optimum or given phase ratio

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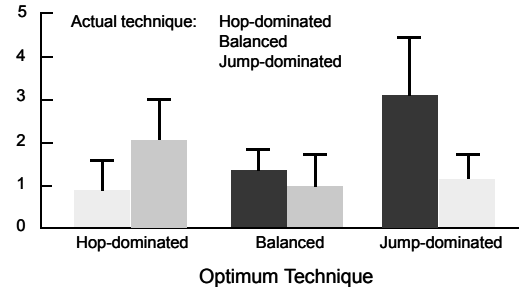
Effects of Optimum Phase Ratio

Loss in actual distance (% Longest distance)



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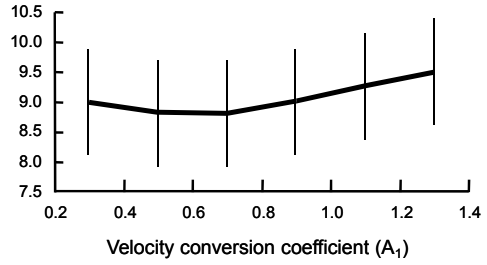
Effects of Optimum Phase Ratio

Actual distance with optimized phase ratio (SH)



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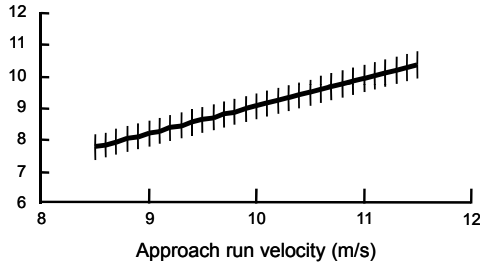
Effects of Optimum Phase Ratio

Actual distance with optimized phase ratio (SH)



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Effects of Optimum Phase Ratio

- Takeoff heights, takeoff distances, touchdown heights, and touchdown distances
  - Little effects on the longest actual distance for men
  - Significant combined effect on the longest actual distance (30% SH) for women

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Effects of Optimum Phase Ratio

- Answers to research questions
  - Phase ratio has a significant effect on actual distance
  - Velocity conversion factor has a significant effect on actual distance
  - Approach run speed has a significant effect on the actual distance

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Effects of Optimum Phase Ratio

- Training of triple jumpers should
  - Increase the magnitude of velocity conversion coefficient
  - Increase approach run velocity
- Training of long jumpers should
  - Decrease the magnitude of velocity conversion coefficient

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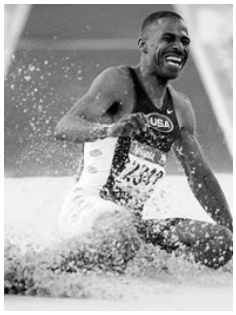
Applications of Research Results

- 1992 Olympic Triple Jump Champion's actual distance = 18.30 m, predicated distance = 18.33 m



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Applications of Research Results

- 1996 US Olympic Trial Triple Jump Champion's actual distance = 18.01 m, predicated distance = 17.99 m
- 1996 Olympic Triple Jump Champion's actual distance = 18.09 m, predicated distance = 18.11 m

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Functions of Arm Motions

Arm Motions

- Three arm swing techniques in the triple jump
  - Alternate-arm swing
  - Double-arm swing
  - Arm-and-half swing

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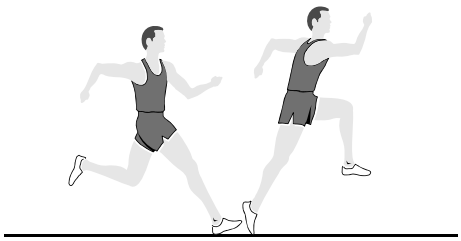
Arm Motions

Alternate-arm swing technique



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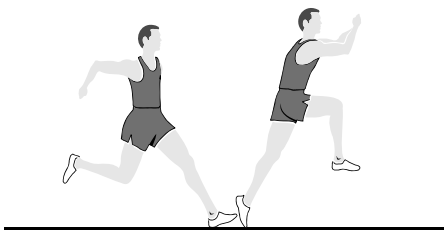
Arm Motions

Double-Arm swing technique



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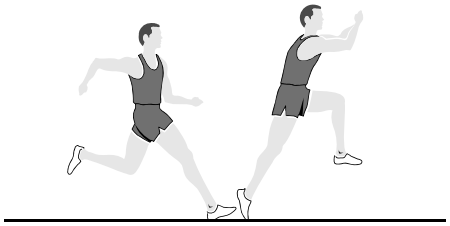
Arm Motions

Arm-and-half swing technique



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Arm Motions

- Research questions
  - What is the function of arm swing motions in triple jump?
  - Which arm swing technique is the optimum for the maximum performance in triple jump?

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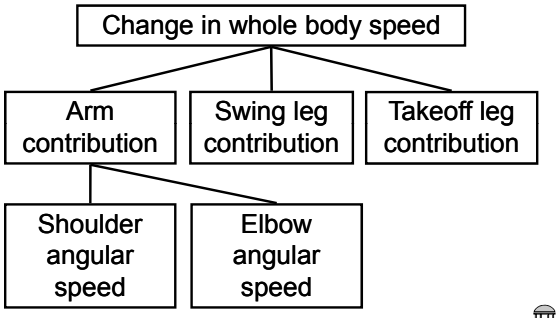
Arm Motions



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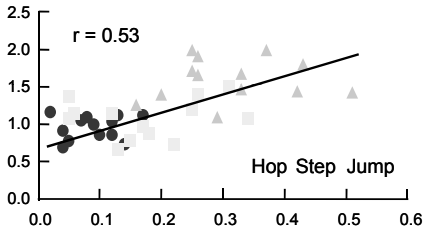
Arm Motions

Loss in whole body horizontal speed (m/s)



Loss in horizontal speed due to arm motions (m/s)

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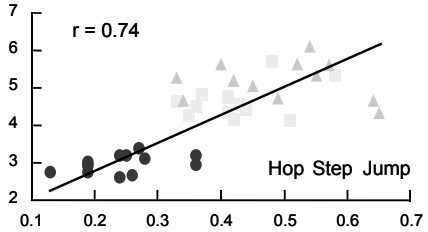
Arm Motions

Gain in whole body vertical speed (m/s)



Gain in vertical speed due to arm motions (m/s)

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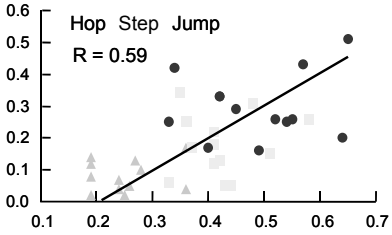
Arm Motions

Loss in horizontal speed due to arm motions (m/s)



Gain in vertical speed due to arm motions (m/s)

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Arm Motions

- A function of arm motions in triple jump
  - Generate vertical speed by converting horizontal speed to vertical speed

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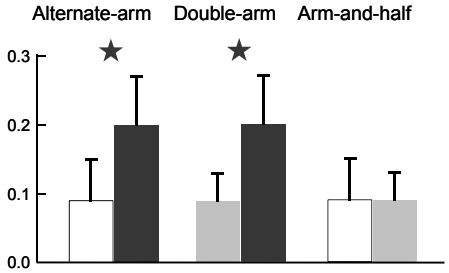
Arm Motions

Loss in Horizontal Speed due to Arm Motions (m/s)



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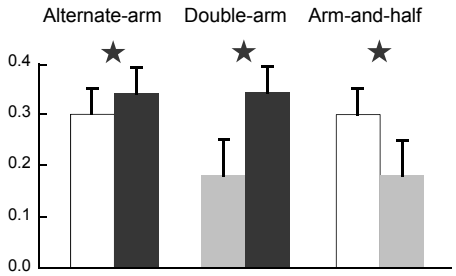
Arm Motions

Gain in Vertical Speed due to Arm Motions (m/s)



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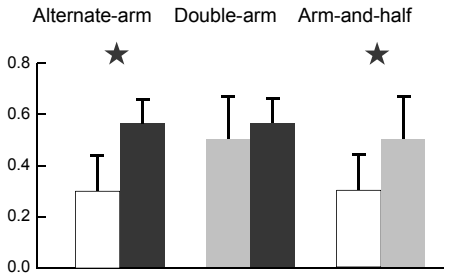
Arm Motions

Speed Conversion Rate of Arm Motions



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Arm Motions

- Optimum arm swing techniques
  - Hop and step — alternate-arm swing to obtain vertical speed and maintain horizontal speed
  - Jump — double-arm swing to obtain maximum vertical speed

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Arm Motions

- Application of research results on arm motions in the triple jump
  - Optimum arm swing in long jump = alternate arm swing
  - Optimum arm swing in high jump = double arm swing

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