HIP CIRCLE TO HANDSTAND ON THE UNEVEN PARALLEL BARS

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Public interest in women's gymnastics has increased over the past two decades as a result of the publicity accorded such performers as Cathy Rigby, Olga Korbut, and Nadia Comenici. Many researchers and gymnastics coaches have sought to explain gymnastics skills through the use of scientific techniques, but because of the dearth of quantitative information available about women's gymnastics, the coach and performer have had to rely on subjective information which has been disseminated from past performers and coaches (Cureton & Welser, 1970). Because there is a lack of scientific information available, gymnastics coaches and performers have tended to adopt the methods and techniques of the current champions, often disregarding correct technique (Wilkerson, 1978). It is the hope of the investigator that the findings of this study may be beneficial to future studies of gymnastics related skills, and may also contribute to the improvement of teaching and coaching the skills performed on the uneven parallel bars.

The scientific problems of this investigation were:

1. to describe the temporal relationships of the kinetic and kinematic variables which contribute to a skillful performance of a clear backward hip circle (CBHC) to handstand;
2. to determine the relationship between selected kinetic and kinematic variables and evaluators' rankings of the quality of performance of a CBHC to handstand; and
3. to expand upon the definitions of a CBHC to handstand currently found in the literature.

The CBHC to handstand may be performed from an inward or outward position on either the low bar or the high bar of the uneven parallel bars (Schmid & Drury, 1977). Figure 1 is a pictorial representation of the CBHC to handstand.

The subjects for this study were four members of the Washington State University women's gymnastics team. The gymnasts were all capable of executing a CBHC to handstand within 20° of vertical in either direction. The means for age, height, and weight of the subjects were 19 years, 160.25 cm, and 541 Newtons, respectively.

The data for this investigation were collected from three sources:

1. strain gages attached along the neutral axis of the bar, for horizontal and vertical bending, 56 cm from each end. These strain gages were connected to a galvonometric type oscillograph, which recorded

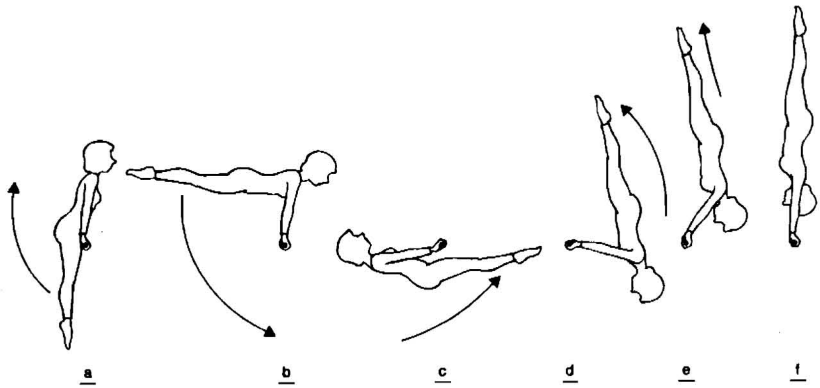

Figure 1 The Clear Backward Hip Circle to Handstand. (Adapted from George, G. S. Biochemics of Women's Gymnastics. Englewood Cliffs: Prentice Hall, 1980, 173.)

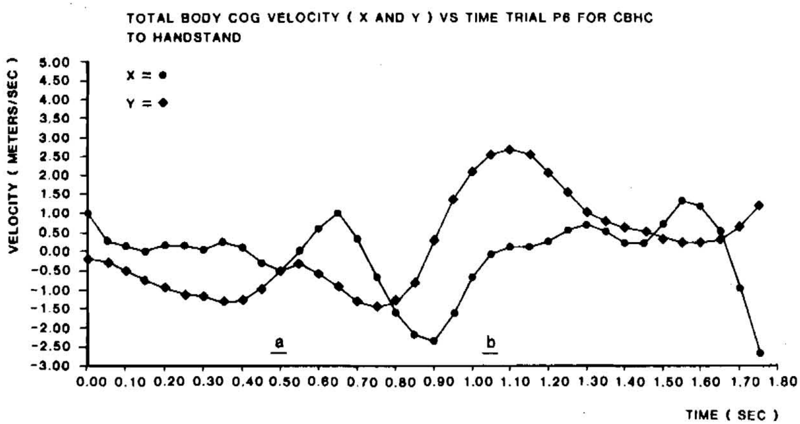

Figure 2 Plot of the total body center of gravity velocity (X and Y) during trial P6 of the Clear Backward Hip Circle to Handstand.

[a] Denotes end of Phase I.

[b] Denotes end of Phase II.

deflections in the bar by means of a light tracing on photosensitive paper;
2. a 16 mm LOCAM camera, operating at a speed of 100 frames per second, which was positioned perpendicular to the plane of motion and 13.1 m from the bars; and
3. a Sony videocorder camera, which was placed perpendicular to the bars, and 7.85 m from the center of the low bar, in order to determine any moves which occurred out of the saggital plane, the plane of motion for the CBHC to handstand.

Three trials for each subject were selected for analysis in this investigation. These 12 trials were viewed on film and scored by a panel of four gymnastics experts in order to determine the quality of performance. These four evaluators used a 10-point scoring sheet designed by the investigator. Any given trial was viewed only once by each evaluator, and the score for each trial was the sum total of the four evaluators' scores for that trial. Based on the total scores, the trials were ranked from 1 to 12, with 1 being the best performance. As Table 1 indicates, trial P6 was evaluated as the best performance, while the three trials by subject L were judged to be the poorest.

Table 1

Results of the Evaluations and the Ranks Assigned to Each Trial

	Evaluators' Scores					
Subject/Trial Code[a]	1	2	3	4	Total	Rank
L1	5.9	7.0	6.1	4.0	23.0	12
L3	5.8	7.8	6.7	4.5	24.8	11
L5	5.6	8.0	7.0	4.5	25.1	10
P2	8.7	8.0	7.1	6.0	29.8	7
P3	9.0	8.3	7.2	6.0	30.5	5
P6	9.1	9.2	8.0	9.0	35.3	1
T3	6.1	7.4	6.0	6.5	26.0	9
T4	7.0	7.9	6.7	7.0	28.6	8
T5	7.7	7.6	7.4	7.5	30.2	6
S1	8.5	8.8	7.3	8.5	33.1	4
S2	8.7	8.9	8.0	8.0	33.6	3
S4	8.7	9.0	7.5	8.5	33.7	2

[a] Letter represents subject's name; number represents trial number.

The CBHC to handstand was divided into 3 phases for the purpose of analysis. Phase I consisted of the time from the top of the cast to the time when the gymnast's body reached a vertical position during descent. Phase II was the time from one frame after the vertical position to one frame before flexion at the shoulders occurred in order for the gymnast to raise her body to the handstand position. Phase III was the time from the initiation of flexion at the soulders until the body reached the handstand position. Phase III is also referred to as the "shoot" portion of the CBHC to handstand.

The left ankle, knee, hip, iliac crest, shoulder, elbow, wrist, and occipito-atlantal joint markings were digitized from the film at five-frame intervals. FILMDATA, a computer program developed by Ralph Mann in 1976, was used to analyze the data points obtained from the film and to calculate and print the results. A subroutine of FILMDATA was also utilized to generate plots of the data. Based on the results from FILMDATA for the smoothed displacement of the total body center of gravity (COG), kinetic energy, work, and power were calculated.

Force-deflection curves were obtained in the horizontal and vertical directions for each of the 12 trials. From these curves, peak forces and impulses were calculated.

In order to investigate the relationships between the variables for which data were quantified, Spearman rank correlations were calculated between the evaluators' rankings of the performances and selected kinetic and kinematic variables. Based on the definitions given by Weber and Lamb (1970), a coefficient between .70 and .89 indicated a high correlation and a coefficient of .90 or greater indicated a very high correlation.

Examination of the plots for the velocity of the total body COG showed some interesting similarities and differences among trials. Figure 2 shows the X and Y components for the COG velocity during trial P6, that trial which was ranked as the best trial by the evaluators. The negative values represent the velocity during the descending portion of the skill, while the positive values occurred as the COG ascended to the handstand position. The maximum velocity during the descending portion for all trials in both the X and Y directions occurred during Phase II, as the COG passed under the low bar. For all trials maximum velocity during the ascending portion of the skill in the X direction occurred as the COG moved over the bar and into the handstand position, at the end of Phase III.

A difference was noted among subjects for maximum ascending velocity of the COG in the Y direction. All trials by subjects P and T reached the maximum at the beginning of Phase III, simultaneous with the "shoot", as Figure 2 indicates. However, Figure 3 shows the differing pattern exhibited by subjects L and S. During these trials, maximum ascending velocity in the Y direction was reached during the middle of Phase II, prior to the "shoot".

Spearman rank correlations were calculated between the evaluators' rankings and the magnitudes of the maximum velocities and accelerations of the COG. The only high correlation was found for negative acceleration of the X component, with the coefficient being .81. Since this maximum acceleration was reached in all trials during Phase II, as the COG began to ascend from the

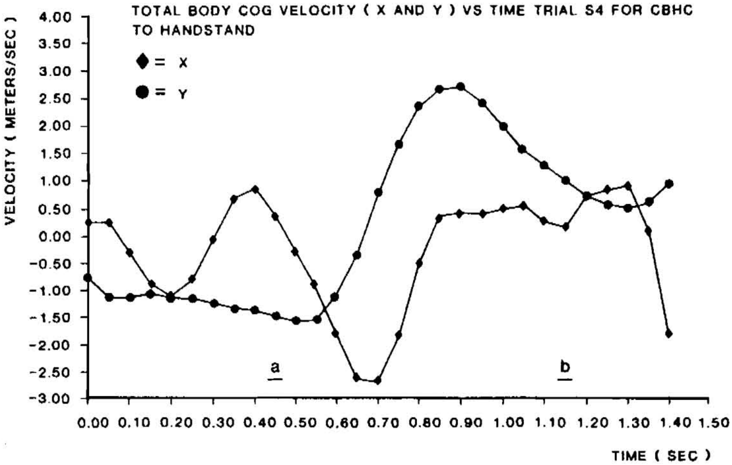

Figure 3 Plot of the total body center of gravity velocity (X and Y) during trial S4 of the clear backward hip circle to handstand.

[a] Denotes end of Phase I.

[b] Denotes end of Phase II.

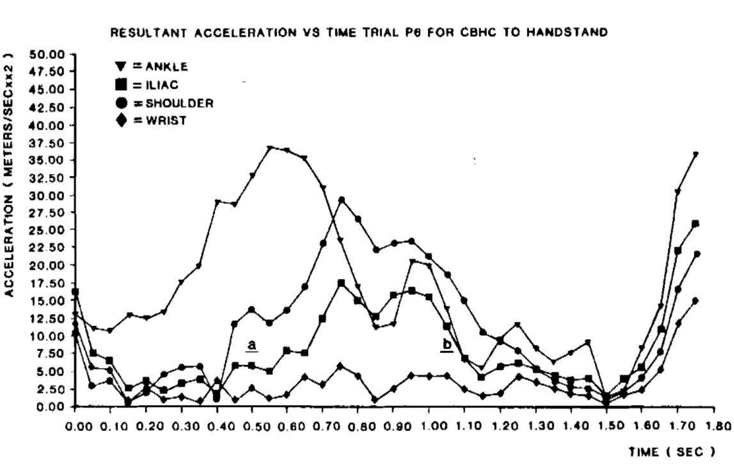

Figure 4 Plot of the resultant acceleration of the ankle, iliac, shoulder, and wrist during trial P6 of the Clear Backward Hip Circle to Handstand.

[a] Denotes end of Phase I.

[b] Denotes end of Phase II.

bottom of the arc, it appeared that at this point in the skill it was beneficial for the X component of the COG to be decelerating as much as possible. This deceleration in the X direction occurred as the Y component of the COG was accelerating, reaching maximum acceleration at the end of Phase III.

With respect to linear kinematics, resultant displacement, velocity and acceleration plots were examined for the ankle, iliac crest, shoulder, and wrist joints. These linear kinematics were similar among all trials, with the exception of the timing of minimum ankle acceleration. In all trials except L3 and L5, minimum ankle acceleration occurred as the handstand was initially attained and the body became stationary (Figure 4). However, for trials L3 and L5 minimum ankle acceleration occurred at the end of Phase II (Figure 5). The reason for this difference was probably due to insufficient velocity for flexion at the shoulder by subject L, which will be more fully discussed later in this presentation.

In terms of angular kinematics, the shoulder and elbow were analyzed. All trials exhibited similar patterns for these two joints, with the exception of the three trials by subject L, who was ranked as the poorest performer of the four subjects. I will present the angular velocity plot for trial P6 as the typical pattern, and compare it to the plot for trial L3 in order to show the different patterns seen in subject L's three trials.

It should be noted that these plots have inverted Y axes, with negative values being at the top of the Y axis (Figure 6). The negative values indicate flexion at the joints whereas the positive values are representative of extension occurring at the joints. The typical pattern showed maximum velocity for flexion at the elbow occurred during the beginning of Phase III, as the gymnast began the shoot to handstand. Maximum velocity for extension at the elbow was in the final portion of Phase III, as the body reached the handstand position.

With respect to angular velocity at the shoulder joint, subjects P, T, and S all reached maximum velocity for flexion at the end of Phase III, as the body reached the handstand position. Maximum velocity for extension at the shoulder occurred during Phase I, as the body descended from the top of the cast.

In contrast to the pattern for the other three subjects, subject L showed maximum velocity for flexion at the elbow at the end of Phase II (Figure 7). Maximum velocity for extension at the elbow occurred during Phase 1 for subject L, as the body descended from the top of the cast.

Subject L exhibited maximum velocity for extension at the shoulder at the end of Phase II, and maximum velocity for flexion at the shoulder at the beginning of Phase III.

The magnitudes for maximum velocity of flexion at the shoulder also appearred to affect the quality of performance. Whereas the mean for all trials was 5.65 r/s, the mean for subject L's three trials was only 3.64 r/s. Since the most important joint in terms of lifting the body to the final vertical position in the CBHC to handstand is the shoulder joint, it appeared that reaching maximum velocity for flexion at the shoulder too early in Phase III, in

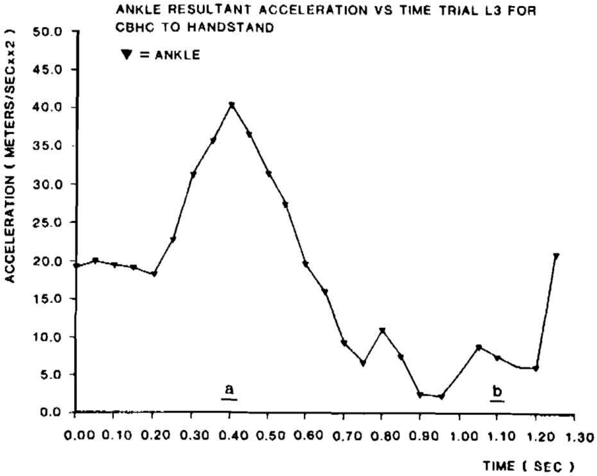

Figure 5 Plot of the resultant acceleration of the ankle during trial L3 of the Clear Backward Hip Circle to Handstand.

[a] Denotes end of Phase I.

[b] Denotes end of Phase II.

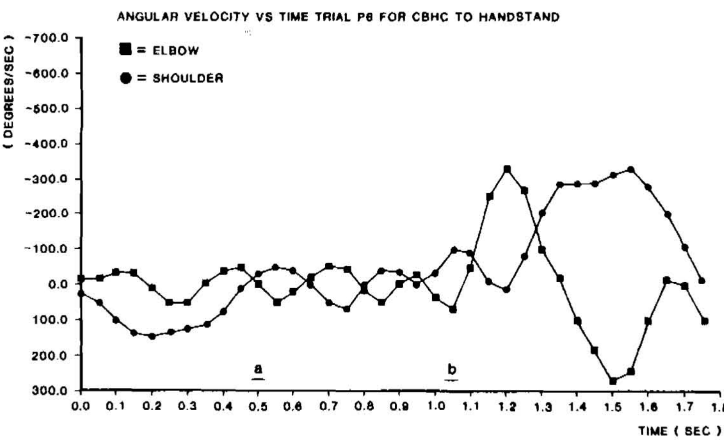

Figure 6 Plot of the angular velocity at the elbow and shoulder during trial P6 of the Clear Backward Hip Circle to Handstand.

[a] Denotes end of Phase I.

[b] Denotes end of Phase II.

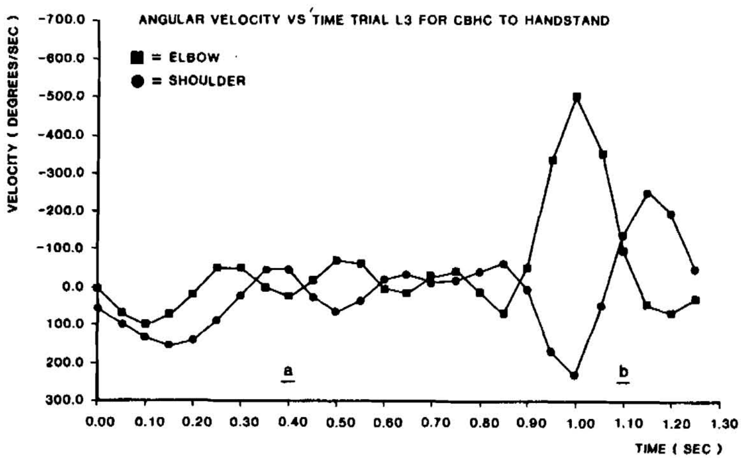

Figure 7 Plot of the angular velocity at the elbow and shoulder during trial L3 for the Clear Backward Hip Circle to Handstand.
[a] Denotes end of Phase I. [b] Denotes end of Phase II.

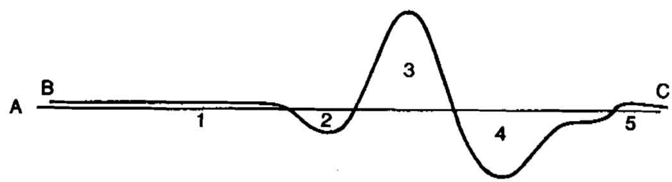

Figure 8 Graphic portrayal of the force-deflection curves (1, 2, 3, 4, 5) for trial P6 of the Clear Backward Hip Circle to Handstand. Line "A" denotes the reference point which was the deflection of the bar when the gymnast was in the front support position. "B" denotes the top of the cast and "C" denotes the handstand position.

addition to not achieving higher magnitudes in flexion velocity at the shoulder, could have contributed to subject L's poor performance.

When observing a gymnast who is in the initial stages of learning a CBHC to handstand, you often see a common error of utilizing flexion and extension at the elbow, rather than flexion at the shoulder, to reach the vertical position. This investigation supported that contention. The poorest performer, subject L, showed the greatest velocities for flexion at the elbow and the lowest velocities for flexion at the shoulder during her 3 trials, of all the 12 trials. Subject P had the lowest velocities for flexion and extension at the elbow during the best of her three trials, P6.

In terms of the kinetic data, force-deflection curves, kinetic energy, work, and power will be discussed. Figure 8 shows the horizontal force-time histories for trial P6. Unfortunately, the vertical force-time histories showed discontinuity, indicating a possible break in the strain gage instrumentation, therefore I do not feel they should be reported until the study can be replicated in order to validate those results.

There were 5 prominent deflections in the horizontal direction for each of the 12 trials. The first deflection occurred during Phase I, as the body descended from the top of the cast (1). This force was directed away from both bars, toward the gymnast's feet. The force shifted horizontally toward the high bar as the gymnast's feet passed under the low bar (2), and again shifted away from both bars as the legs passed under the low bar (3). At the beginning of the "shoot" the force was again directed horizontally toward the high bar as the gymnast began maximum flexion at the shoulder (4). There was a final horizontal force directed away from both bars just before the gymnast reached the handstand position (5).

The magnitudes of the peak forces in the horizontal direction were as high as six times body weight, which agreed with the relevant literature (Dusenbury, 1968; Hay, Putnam, & Wilson, 1979; Sale & Judd, 1974). This literature reported values ranging from five times body weight to nine times body weight for both males and females performing various gymnastic skills of a swinging nature.

The vertical forces with respect to distance and time of application were calculated from the kinematic data as kinetic energy, work, and power (Table 2). Negative work and power occurred as the COG descended from the top of the cast, with the positive values resulting from the ascent of the COG. Spearman rank correlations were calculated between the evaluators' rankings and the total positive and negative work and power values. A very high coefficient of -0.93 was found for positive work and power, indicating that better performances of the CBHC to handstand resulted in greater amounts of work and power being performed as the COG ascended from under the bar to the handstand position.

To summarize, I would like to give some pointers which could be beneficial to gymnastics coaches and teachers who are working with performers executing a CBHC to handstand. These teaching cues are based on the findings of this investigation.

1. There should be as little resistance as possible during the body's descent from the top of the cast in order to attain maximum COG velocity at the bottom of the arc, and maximum linear velocity at the distal joints. The hands should merely maintain contact with the bar,

Table 2

Maximum Kinetic Energy, Total Negative and Positive Work and Power Performed During the Execution of a Clear Backward Hip Circle to Handstand

Subject/ Trial	K.E.[a]	Neg. Work[b]	Pos. Work[b]	Neg. Power[c]	Pos. Power[c]
L1	3.95	368.28	376.25	7365.68	7525.00
L3	6.42	371.68	402.81	7433.51	8056.14
L5	2.95	404.22	381.41	8084.41	7628.24
P2	6.89	465.00	470.07	9300.03	9401.43
P3	2.19	418.56	489.07	8371.14	9851.40
P6	4.30	391.70	494.05	7833.98	9881.01
T3	4.29	360.90	429.83	7218.06	8596.52
T4	1.50	381.85	479.56	7637.09	9591.11
T5	4.64	373.30	478.31	7466.00	9566.10
S1	4.31	417.27	549.28	8345.48	10985.69
S2	6.70	417.91	558.04	8358.24	11160.85
S4	5.72	418.84	559.08	8376.85	11181.53
Mean	4.48	399.13	472.31	7982.54	9452.09
S.D.	1.73	30.15	64.51	603.03	1292.00
Min.	1.50	360.90	376.25	7218.06	7525.00
Max.	6.89	465.00	559.08	9300.00	11181.55

[a]All kinetic energy values are presented in Joules.

[b]All work values are presented in Joules.

[c]All power values values are presented in Watts.

thus minimizing the effect of friction as much as possible. The body should swing freely, as does a pendulum, in order to reap the greatest benefits of the principles of pendular motion.

2. The optimal angle to attain at the top of the cast is between 8^0 and 12^0 above the horizontal. This optimal angle should be reached consistently in order to aid the performer in maximizing the principles of pendular motion during descent.

3. Gymnastics coaches and teachers who observe elbow flexion and extension by their performers during the execution of a CBHC to handstand, should investigate what is occurring at the gymnast's shoulder joints. It appeared from this study that insufficient velocity for flexion at the shoulder resulted in compensation on the part of the subjects by utilizing flexion and extension at the elbow joints. That is to say, the coaches' advice might center on the desired action at the shoulder rather than the undesired action at the elbow.
4. The "slip-grip" action of the hands should occur when the moment at the hands/bar interface is minimal, approximately 15° before the handstand position, in order to minimize the chance of injury to the gymnast as a result of the hands "peeling-off" the bar if the "slip-grip" occurs when the moment at the bar is still great.
5. Spotting of swinging moves in gymnastics is important for the safety of the gymnast. In terms of the CBHC to handstand, spotting is most crucial as the gymnast's hands undergo the "slip-grip" action.
6. In order to attain the greatest amount of kinetic energy as the COG passes beneath the bar, the gymnast should keep her COG as far from the bar as possible during the downswing.

One of the specific problems of this study was to expand upon the definitions of a CBHC to handstand currently found in the literature. Although the cast portion of the CBHC to handstand was not analyzed in this investigation, the biomechanical description includes the cast, with the gymnast beginning in a front support position.

From the front support position the gymnast initiates the cast with the hands in a regular grip; the hips pike swinging the legs under the bar, then the legs extend lifting the hips off the bar with the gymnast rising to a clear front support position at an angle between 8° and 12° above the horizontal. From the top of the cast the body rotates backward past the horizontal in order to initiate a pendular swing, followed by the shoulders rotating backward to a point behind the hands. During this phase of the skill the arms are extended and there is slight flexion at the hips (foot-lead position), with the axis of rotation initially at the shoulder joints. As the swing continues, two axes of rotation will exist, one at the hands/bar interface and the other remaining at the shoulders. When the upper part of the thighs ascend to the level of the bar the angular momentum of the legs and trunk about the shoulder joints is transferred into backward rotatory motion of the entire body. As the head approaches a position directly below the bar the performer begins extending out of the foot-lead position and the pendular swing as she initiates forceful flexion at the shoulders. This results in deceleration in the horizontal direction and an attempt to produce movement linearly in the vertical direction. The hands undergo a "slip-grip" action approximately 15° before the terminal handstand position as all body segments simultaneously align with the upper vertical. There should be full flexion at the shoulders, full extension at the elbows, hips, and knees, the feet should be plantar flexed (toes pointed), and the head should be in a neutral position between the arms during the handstand.

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