Athletes with high knee abduction moments show increased vertical center of mass excursions and knee valgus angles across sport-specific fake-and-cut tasks of different complexities

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Zitiervorschlag im APA Stil:

Bill, K., Mai, P., Willwacher, S., Krosshaug, T., & Kersting, U. G. (2022). Athletes with high knee abduction moments show increased vertical center of mass excursions and knee valgus angles across sport-specific fake-and-cut tasks of different complexities. *Frontiers in Sports and Active Living*, *4*, 1–13. https://doi.org/10.3389/fspor.2022.983889

Abstract

Young female handball players represent a high-risk population for anterior cruciate ligament (ACL) injuries. While the external knee abduction moment (KAM) is known to be a risk factor, it is unclear how cutting technique affects KAMs in sport-specific cutting maneuvers. Further, the effect of added game specificity (e.g., catching a ball or faking defenders) on KAMs and cutting technique remains unknown. Therefore, this study aimed: (i) to test if athletes grouped into different clusters of peak KAMs produced during three sport-specific fake-and-cut tasks of different complexities differ in cutting technique, and (ii) to test whether technique variables change with task complexity. Fifty-one female handball players (67.0 ± 7.7 kg, 1.70 ± 0.06 m, 19.2 ± 3.4 years) were recruited. Athletes performed at least five successful handball-specific sidestep cuts of three different complexities ranging from simple pre-planned fake-and-cut maneuvers to catching a ball and performing an unanticipated fake-and-cut maneuver with dynamic defenders. A k-means cluster algorithm with squared Euclidean distance metric was applied to the KAMs of all three tasks. The optimal cluster number of koptimal = 2 was calculated using the average silhouette width. Statistical differences in technique variables between the two clusters and the tasks were analyzed using repeated-measures ANOVAs (task complexity) with nested groupings (clusters). KAMs differed by 64.5%, on average, between clusters. When pooling all tasks, athletes with high KAMs showed 3.4° more knee valgus, 16.9% higher downward and 8.4% higher resultant velocity at initial ground contact, and 20.5% higher vertical ground reaction forces at peak KAM. Unlike most other variables, knee valgus angle was not affected by task complexity, likely due to it being part of inherent movement strategies and partly determined by anatomy. Since the high KAM cluster showed higher vertical center of mass excursions and knee valgus angles in all tasks, it is likely that this is part of an automated motor program developed over the players' careers. Based on these results, reducing knee valgus and downward velocity bears the potential to mitigate knee joint loading and therefore ACL injury risk.

Athletes With High Knee Abduction Moments Show Increased Vertical Center of Mass Excursions And Knee Valgus Angles Across Sport-Specific Fake-And-Cut Tasks of Different Complexities

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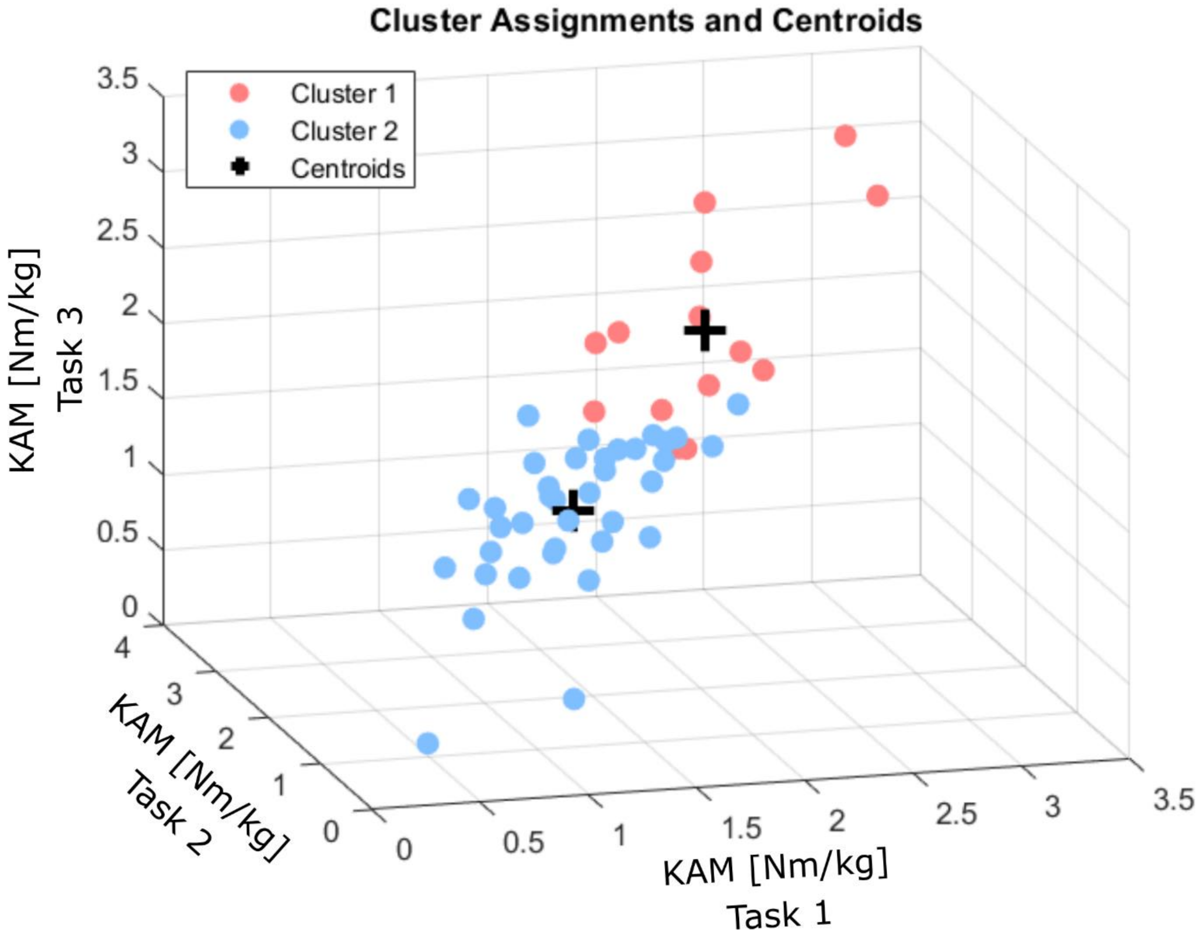
Appendix 1. League affiliation of athletes.

League	Cluster 1 *n*	Cluster 1 Relative Share [%]	Cluster 2 *n*	Cluster 2 Relative Share [%]	Total *n*	Total Relative Share [%]
REMA 1000-ligaen*	2	14.3	4	10.8	6	11.8
First Division	2	14.3	5	13.5	7	13.7
Second Division	6	42.9	15	40.5	21	41.2
Third Division	2	14.3	5	13.5	7	13.7
Junior	1	7.1	7	18.9	8	15.7
Other	1	7.1	1	2.7	2	3.9

Appendix 2. Field positions of athletes. Numbers do not add up to 14 (Cluster 1), 37 (Cluster 2) and 51 (total) due to athletes playing multiple positions.

Position	Cluster 1 *n*	Cluster 1 Relative Share [%]	Cluster 2 *n*	Cluster 2 Relative Share [%]	Total *n*	Total Relative Share [%]
Back	10	71.4	31	83.8	41	80.4
Line	2	14.3	2	3.9	4	7.8
Wing	3	21.4	11	29.7	14	27.4



Appendix 3. Cluster assignments and centroids based on the average peak external knee abduction moments within the first 100 ms of stance. Each data point represents one subject.

Appendix 4. Number of athletes with previous ACL injuries.

Previous ACL Injury	Cluster 1		Cluster 2		Total	
	n	Relative Share [%]	*n*	Relative Share [%]	*n*	Relative Share [%]
Cutting Leg	0	0	1	2.7	1	2.0
Non-Cutting Leg	1	7.1	4	10.8	5	9.8
Both Legs	0	0	1	2.7	1	2.0

Appendix 5. Technique variables and their magnitudes for all three tasks, results of repeated-measures ANOVAs and pairwise comparisons.

Variable	Task 1	Task 2	Task 3	Task Effect	Pairwise Comparison		
				p_{task}	Task 1 vs. 2	Task 1 vs. 3	Task 2 vs. 3
Peak KAM (First 100 ms of Stance) [Nm/kg]	1.52 ± 0.54	1.73 ± 0.61	1.64 ± 0.56	**< .001**	**.003**	**.022**	.37
Foot Strike Angle at IC [°]	3.2 ± 12.5	-2.1 ± 13.5	6.8 ± 9.9	**< .001**	**< .001**	**.010**	**< .001**
Foot Progression Angle at IC [°]	-8.2 ± 4.2	-9.5 ± 5.2	-10.7 ± 4.6	**.002**	.27	**< .001**	.16
Knee Flexion Angle at IC [°]	24.6 ± 6.3	22.9 ± 5.1	24.3 ± 7.7	**.016**	**.023**	1	.06
Knee Valgus Angle [°] at IC	6.3 ± 3.8	5.8 ± 3.4	6.5 ± 3.6	.11	–	–	–
Hip Abduction Angle at IC [°]	17.4 ± 4.2	17.9 ± 4.9	18.8 ± 4.7	**.006**	0.41	**.017**	.166
Hip Rotation Angle at IC [°]	-1.9 ± 5.2	-1.7 ± 5.0	-1.6 ± 4.6	.72	–	–	–
Trunk Lateral Flexion Angle at IC [°]	8.1 ± 6.2	6.4 ± 6.7	7.8 ± 6.4	**.028**	.06	1	.06
Trunk Rotation Angle at IC [°]	-18.2 ± 10.4	-22.2 ± 11.7	-20.6 ± 10.5	**.014**	**.019**	.33	.69
Trunk Rotation Velocity at IC [°/s]	-70.7 ± 93.0	-105.7 ± 111.7	-85.7 ± 98.8	**.008**	**.034**	.46	.10
Horizontal CoM Velocity at IC [m/s]	2.91 ± 0.35	3.15 ± 0.34	2.96 ± 0.35	**< .001**	**< .001**	.64	**< .001**
Resultant CoM Velocity at IC [m/s]	3.34 ± 0.29	3.52 ± 0.31	3.34 ± 0.31	**< .001**	**< .001**	1	**< .001**
Anterior CoM Velocity [m/s]	2.70 ± 0.35	2.94 ± 0.35	2.78 ± 0.34	**< .001**	**< .001**	.19	**< .001**
Lateral CoM Velocity [m/s]	1.05 ± 0.30	1.08 ± 0.32	0.98 ± 0.28	**.046**	1	.46	.07
Vertical CoM Velocity [m/s]	1.59 ± 0.34	1.54 ± 0.28	1.51 ± 0.32	**.025**	.32	**.046**	.71
Vertical GRF at Peak KAM [N/kg]	27.59 ± 5.73	28.51 ± 5.71	27.00 ± 6.53	**.038**	.41	.87	**.034**
Cut Angle [°]	70.8 ± 14.0	69.2 ± 14.9	61.5 ± 14.0	**.002**	.78	**< .001**	**< .001**
Cut Width at IC [°]	21.1 ± 2.5	21.5 ± 2.8	22.8 ± 3.1	**< .001**	.75	**< .001**	**.008**
Contact Time [s]	0.30 ± 0.05	0.31 ± 0.05	0.29 ± 0.04	**.002**	.32	**.008**	**< .001**