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Exploring the Dynamics of Hamstring Strength in Volleyball: a Positional Perspective Through a Cross-sectional Lens

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Abstract

No previous studies have examined the isolated eccentric hamstring strength according to the playing positions of volleyball players, but there are a few studies evaluating hamstring muscle strength based on playing positions. The aim of this study was to compare the eccentric hamstring muscle strength levels of elite volleyball players according to their playing positions. Elite volleyball players (n=31 female and n=32 male) aged between 18-35 who participated in the 2022-2023 Turkish Volleyball 1st League season and followed a similar training program were included in the study voluntarily. Sixty-three volleyball players were categorized as libero (n=5 female and n=6 male), middle player (n=8 female and n=8 male), opposite (n=4 female and n=6 male), setter (n=6 female and n=4 male), and spiker (n=7 female and n=9 male). Eccentric hamstring muscle strength was assessed during the Nordic Hamstring Exercise (NHE) using the IVMES H-Bord (IVMES, Ankara, Turkey) device. The comparison of the eccentric hamstring strength of the volleyball players according to their positions revealed no statistically significant difference between the maximum and mean eccentric hamstring muscle strengths and muscle strength differences for both female (F=0.403-5.331; p=0.255-0.982) and male (F=4.167-6.985; p=0.137-0.384) athletes. Additionally, there was no significant difference between male and female athletes in terms of mean and maximum eccentric hamstring muscle strength and muscle strength differences based on their positions (F=0.001-3.823; p=0.055-0.972). Our study found that the eccentric hamstring strength and bilateral strength difference percentages of both male and female volleyball players did not differ according to their positions. The fact that the eccentric hamstring strength levels of volleyball players did not differ according to positions in previous studies and in our study is thought to be related to the evolving structure of volleyball.

Keywords: Eccentric muscle strength, hamstring, playing position, volleyball.

Voleybolda Hamstring Gücü Dinamiklerinin Araştırılması: Kesitsel Bir Mercekten Konumsal Bir Perspektif

Özet

Bilgimiz dahilinde literatürde izole eksantrik hamstring kuvvetini voleybol oyuncularının oyun pozisyonlarına göre inceleyen bir çalışma bulunmamakla birlikte, hamstring kas kuvvetini oyun pozisyonlarına göre değerlendiren az sayıda çalışma bulunmaktadır. Bu araştırmanın amacı, elit voleybolcuların eksantrik hamstring kas kuvvetlerinin oyun pozisyonlarına göre karşılaştırmaktır. Araştırmaya, 2022-2023 Türkiye Voleybol 1. Lig sezonunda yer alan, benzer antrenman programına alınan 18-35 yaş aralığında 63 (n=31 kadın ve n=32 erkek) elit voleybol sporcusu gönüllü katılmıştır. Sporcular libero (n= 5 kadın ve n=6 erkek), orta oyuncu (n=8 kadın ve n=8 erkek), pasör çaprazı (n= 4 kadın ve n=6 erkek), pasör (n= 6 kadın ve n=4 erkek) ve smaçör (n=7 kadın ve n=9 erkek) olarak kategorize edildi. Sporcuların eksantrik hamstring kas kuvvetleri Nordic Hamstring egzersizi (NHE) sırasında IVMES H-Bord (IVMES, Ankara, Türkiye) kullanılarak yapıldı. Voleybolcuların pozisyonlarına göre eksantrik hamstring kuvvetleri karşılaştırıldığında, hem kadın (F=0.403-5.331; p=0.255-0.982) hem de erkek (F=4.167-6.985; p=0.137-0.384) sporcuların maksimum ve ortalama eksantrik hamstring kas kuvvetleri ve kas kuvveti farklılıkları arasında istatistiksel olarak anlamlı bir fark bulunmamıştır. Ayrıca, kadın ve erkek sporcular arasında ortalama ve maksimum eksantrik hamstring kas kuvveti ve pozisyonlarına göre kas kuvveti farklılıkları açısından anlamlı bir fark bulunmamıştır (F=0.001-3.823; p=0.055-0.972). Çalışmamızda hem kadın hem erkek voleybol oyuncuların eksantrik hamstring kuvvetleri ve iki taraf arası kuvvet farklılık yüzdeleri mevkilere göre farklılık göstermediği bulundu. Geçmiş araştırmalarda ve araştırmamızda, voleybolcuların eksantrik hamstring kuvvet düzeylerinin mevkilere göre farklılık göstermemesi, voleybolun değişen yapısı ile ilgili olduğu düşünülmektedir.

Anahtar Kelimeler: Eksantrik kas kuvveti, hamstring, oyun pozisyonu, voleybol.

INTRODUCTION

Hamstrings are the muscle group with the highest injury rate and risk. Hamstring injuries constitute a significant portion of sports-related muscle injuries, accounting for 54.4% of such injuries (1). This high incidence rate underscores the vulnerability of the hamstring muscles, particularly in activities that involve high-intensity running and sudden accelerations or decelerations. The prevalence of hamstring injuries has a substantial impact on athletes, often causing them to be sidelined for extended periods and resulting in decreased performance across various sports disciplines. Hamstring muscle injuries (HMI) are especially common in running-based sports such as athletics, football, American and Australian football, and rugby (1, 2). The ramifications of these injuries extend beyond the athletic arena, contributing to increased labor force losses and heightened costs for both sedentary individuals and sports clubs. This highlights the broader economic and performance-related consequences of hamstring injuries, emphasizing the need for effective prevention and rehabilitation strategies (3). In order to prevent HMI, it is important to understand why they occur so that an appropriate approach targeting specific risk factors can be developed. Among the factors that lead to HMI are advanced age, history of hamstring injury, decreased eccentric hamstring muscle strength, imbalance in the ratio of hamstring muscle strength to quadriceps muscle strength, delay in hamstring reaction time leading to muscle fatigue, poor lumbopelvic stability, and impaired hamstring muscle architecture (3, 4).

Eccentric knee flexor muscle weakness is arguably the most frequently reported risk factor for HMI. Eccentric hamstring muscle strength deficits have been identified as a risk factor for recurrent HMI. This result suggests that weakness is a predisposing factor for both new and recurrent ACL. Therefore, the assessment of hamstring muscle eccentric strength at different stages of the season is considered a key strategy for the deliberate prevention of ACL (4, 5). The multidimensional role of hamstring strength in athletic performance is well understood and the direct contribution of hamstring strength to athletic skills such as sprinting and jumping has been demonstrated in several studies (6, 7). Hamstring strength also plays an important role in knee joint stabilisation and indirectly influences the qualities of agility manoeuvres such as acceleration, deceleration, changing direction and cutting (8). It has also been suggested that hamstring weakness increases the risk of ACL, which is a typical sports injury and occurs in sports such as athletics and volleyball that require high sprint speed and/or simultaneous excessive muscle tension (9). Low hamstring strength or inadequate activation is associated with non-contact anterior cruciate ligament (ACL) injuries, which are particularly high in team sports such as football and volleyball. In particular, as a synergist of the ACL, the lateral hamstring muscle spans two joints and provides secondary protection, especially at smaller joint angles (10).

Vertical jumping is a very important skill in volleyball and is important during blocking, attacking and passing (11, 12). A high level of knee muscle strength is required during the take-off and landing phases of the vertical jump, which requires high torque and power in concentric and eccentric movements of the knee extensor and flexor muscles (13). During a volleyball player's career, an increase in the intensity and frequency of training may lead to acute and chronic injuries and athletes may quit the sport (14). These events can be explained by strength imbalances between muscle groups or between dominant and non-dominant limbs, which predispose the joint to instability and ligament overload (15-17). Therefore, it is important to measure knee muscle strength and determine agonist-antagonist muscle imbalances in preparing training guidelines to reduce the risk of injury and increase muscle strength (13, 18, 19). In many prospective studies in the literature, the effects of eccentric and concentric knee flexor muscle strength on hamstring injury rates have been investigated (3, 20-23). However, most of these studies have been performed on footballers and studies in volleyball players are insufficient. To the best of our knowledge, there is no study comparing eccentric hamstring muscle strength in volleyball players according to their positions. In addition, this study was hypothesised that there would be a difference in eccentric hamstring strength parameters between dominant and non-dominant side legs of volleyball players according to their positions. In this context, the aim of this study was to compare the eccentric hamstring muscle strength of elite volleyball players according to their playing positions.

METHOD

In the study, 63 (n=31 female and n=32 male) elite volleyball players between the ages of 18-35 (n=31 female and n=32 male) participated voluntarily in a similar training programme in the Turkish Volleyball 1st League season. The athletes were categorized into their playing positions based on their roles and responsibilities within their respective teams. The categorization was as follows: libero (n=5 females and n=6 males), middle player (n=8 females and n=8 males), opposite (passer cross, n=4 females and n=6 males), setter (passer, n=6 females and n=4 males), and spiker (n=7 females and n=9 males). These positions were determined by the specific functions each athlete performed during matches and training sessions. Liberos are defensive specialists responsible for receiving serves and playing in the back row. Middle players, or middle blockers, are primarily responsible for blocking and quick attacks at the net. Opposites, or passers cross, play a versatile role, often involved in both offensive and defensive plays. Setters, or passers, are responsible for setting up offensive plays by delivering accurate sets to attackers. Spikers, or outside hitters, are the primary attackers on the team, responsible for scoring points through powerful hits. This categorization ensured that each player's position was accurately represented according to their specialized skills and duties on the court. The required sample size was calculated using G*Power (G*Power, Ver.3.0.10, Universitat Kiel, Germany) programme with alpha= 0.05, beta=0.20 (Power 80%) and f=0.40 (effect size; f >0.10 small, >0.25 medium, >0.40 large) effect size and the number of participants was calculated as minimum 10 for each group (24, 25). The inclusion criteria were determined as being a professional volleyball athlete between the ages of 18-35 years, playing active and licensed sports for at least three years, not having any injury related to the lower extremity and hamstring in the last 3 months, not having any surgical operation in the lower extremity, and having regular participation in training during the study. Those who had any illness or injury that could affect performance in the last 6 months, those who had an injury that would keep them away from sports for more than 2 weeks in the last 3 months, and those who had Covid-19 in the last 6 months were not included.

Data Collection and Analysis

Sociodemographic data such as age, height, body weight, gender, dominant side, and years of sport were recorded. The dominant lower extremity was defined as the extremity in which the player takes the last step during jumping (26). It was found that 23.25% (n=10) of the athletes included in the study were left dominant and 76.25% (n=33) were right dominant. Body weight and body mass index were measured using a bioelectrical impedance analyser (Tanita 300 MA, Tanita Co., Tokyo-Japan) and height was measured using a stadiometer (SECA 213, Seca GmbH & Co. Kg, Hamburg, Germany). Eccentric hamstring muscle strength of the athletes was measured during Nordic hamstring exercise using iVMES H-BORD® [iVMES, Ankara, Turkey; Sampling Rate: 50 Hz (default) - 400 Hz, Capacity (per sensor): 1000 N / 100 kg, Safe Overload (per sensor): 1500 N / 150 kg, Maximum Overload (per sensor/2 sensors): 2000 N / 200 kg, Resolution: 1 N] measured with the device (Figure 1).

Figure 1: iVMES H-BORD®

Eccentric Hamstring Muscle Strength Measurement

Eccentric hamstring muscle strength of the athletes was measured during Nordic hamstring exercise (NHE) using IVMES H-Bord (IVMES, Ankara, Turkey) [Intraclass correlation coefficient (ICC)=0.90-097] (27). Before the test, NHE was performed at submaximal intensity with 1 set of 3 repetitions in order to understand and familiarise the movement. Nordic Hamstring exercise protocols were performed in eccentric mode with a maximum of 3 eccentric movements in 1 set. Rest was given for 2 minutes between each repetition. Each trial was recorded from the sagittal plane using a Canon XA35 camera at 50 Hz. The camera was placed on a stand fixed 3 m away from the participant and 0.5 m high (28). The angular changes required to determine the movement quality of each participant were calculated using reflective markers placed on the anatomical prominences of the greater trochanter, lateral femoral condyle and lateral malleolus, which have been reported in previous studies (9, 27). Measurements were performed with minimal clothing to prevent movement of the markers. Participants were placed in a kneeling position on the padded section of the device and each ankle was secured at the top of the lateral malleolus with separate supports. Participants were instructed to gradually lean forward from an upright position (90° knee flexion) at the slowest possible speed, maximally resisting the movement with both extremities, while keeping their trunk and hips in a neutral position with their hands on their chest. The NHE performance was completed at -30°-s-1 in accordance with previous studies (29, 30). If the participants were unable to meet the 30°-s-1 forward bending speed (as a result of video analyses), the NHE trials were repeated. The movement technique required participants to minimise hip flexion and lumbar lordosis throughout the repetitions to maintain a straight line from shoulder to knee. If participants showed a lack of control during landing or excessive hip movement during the repetition as a result of the video analyses, these repetitions were not included in the calculation. NHE trials in which hip flexion exceeded 20° at any time point and/or NHE trials with a mean forward bending velocity outside 20-40° s-1 were not included in the analyses. The values obtained from the device are maximum force, mean force and imbalance values within three repetitions for the right and left hamstring muscles, respectively.

Statistical Analysis

SPSS Version 26 (IBM SPSS® software, US) programme was used for statistical analysis of the data. The conformity of the data to normal distribution was evaluated visually and by Shapiro-Wilk test. Numerical variables were summarised as mean±standard deviation and categorical variables as frequency (percentage). In intergroup comparisons, one-way analysis of variance (ANOVA) was used for numerical variables and Pearson Chi-square test was used for categorical variables. The statistically significant level was set as $p < 0.05$.

FINDINGS

Table 1. Data on the comparison of the physical characteristics of the participants according to their positions

		Libero (n=11)	Middle player (n=16)	Opposite (n=10)	Setter (n= 10)	Wing Spiker (n=16)	Test statistics	
		Mean±Sd	**Mean±Sd**	**Mean±Sd**	**Mean±Sd**	**Mean±Sd**	**F**	**p**
Age (years)	M	18.0±0.70	18.7±1.48	20.0±6.06	21.2±7.36	22.8±6.09	0.577	0.681
	F	23.0±3.87	22.1±4.77	19.2±2.62	20.0±4.42	20.3±7.04		
Height (m)	M	1.90±0.04	1.89±0.03	1.84±0.03	1.81±0.04	1.90±0.02	0.778	0.312
	F	1.88±0.03	1.89±0.01	1.86±0.02	1.82±0.03	1.88±0.02		
Weight (kg)	M	77.20±3.96	71.75±6.96	71.00±0.90	66.25±5.31	74.90±7.13	0.782	0.215
	F	73.2 ±5.83	76.85±3.13	68.75±3.59	65.16±4.79	70.28±5.93		
BMI (kg/m2)	M	21.32±0.20	19.95±1.55	20.87±0.75	20.09±1.10	20.53±1.73	0.378	0.789
	F	20.65±1.67	21.50±0.55	19.71±0.96	19.62±1.00	19.80±1.31		
Sport experience (years)	M	4.06±0.04	4.16±1.02	4.76±2.34	4.37±1.46	4.51±1.76	0.390	0.897
	F	3.86±1.11	4.44±0.97	4.53±1.87	4.41±1.51	4.22±1.64		
							X2	p
D-Side (n)	Right	8	13	10	7	15	6.831	0.145
	Left	3	3	0	3	1		
Gender (n)	M	6	8	6	4	9		
	F	5	8	4	6	7	1.367	0.850

Mean±Sd: Mean±Standard deviation / F: ANOVA test, X2 : Pearson Chi-square test, BMI: Body mass index, D: Dominant, M: Male, F: Female, m: meter, kg: kilogram

It was found that there was no significant difference in age, height, body weight, body mass index (BMI), years of sport and dominant extremity values of volleyball players according to their positions (Table.1).

Table 2: Hamstring strength comparison by player position

	Libero (n=11)	Middle player (n=16)	Opposite (n=10)	Setter (n= 10)	Wing Spiker (n=16)	Test statistics	
	Mean±Sd	Mean±Sd	Mean±Sd	Mean±Sd	Mean±Sd	F	p
Max HEcc D (N)	332.40±103.58	352.32±77.18	355.50±78.88	261.97±27.95	275.91±61.45	6.979	0.137
	244.38±63.55	275.34±58.92	264.21±38.88	261.03±48.30	314.27±49.44	3.490	0.479
F;p	3.201;0.111	0.851;0.373	0.485;0.506	1.532;0.251	0.064;0.804	0.173	0.679
Max HEcc ND (N)	331.04±106.13	321.96±78.29	339.70±65.36	256.05±26.45	265.09±65.96	6.985	0.137
	248.32±63.84	282.14±58.50	254.71±41.21	272.01±46.30	307.54±36.31	4.963	0.291
F;p	1.664;0.233	2.374;0.147	0.537;0.485	1.548;0.249	0.129;0.724	0.080	0.778
Mean HEcc D (N)	307.86±90.92	311.61±63.93	342.35±58.51	243.75±39.29	246.50±50.40	5.525	0.238
	224.46±66.43	268.90±43.04	239.26±50.21	240.46±37.13	304.90±49.56	5.331	0.255
F;p	0.009;0.926	1.890;0.192	0.614;0.456	0.890;0.373	1.415;0.252	0.001	0.972
Mean HEcc ND (N))	310.24±87.95	294.11±72.48	325.92±56.66	245.95±38.77	237.02±52.87	6.770	0.149
	220.02±74.15	257.44±39.54	236.05±52.11	257.71±52.54	280.65±41.91	3.229	0.520
F;p	1.074;0.330	2.919;0.111	1.378;0.274	0.938;0.361	0.024;0.878	0.044	0.835
Max difference (%)	8.84±0.08	11.30±1.93	14.21±1.44	4.90±0.72	11.56±3.24	4.167	0.384
	9.56±0.25	7.61±0.43	5.15±0.24	8.70±1.80	8.64±1.33	0.403	0.982
F;p	0.066;0.804	1.666;0.219	1.469;0.260	2.143;0.181	1.847;0.193	3.823	0.055
Mean difference (%)	7.72±0.67	10.23±1.63	13.58±1.86	3.75±0.30	9.97±1.98	4.670	0.323
	4.90±0.78	6.64±0.68	4.52±0.05	8.70±1.74	6.77±1.52	1.963	0.743
F;p	2.625;0.144	0.008;0.931	1.505;0.255	3.533;0.097	0.002;0.963	0.985	0.325

Max HEcc: Maximum eccentric hamstring strength, Mean HEcc: Average eccentric hamstring strength, D: Dominant side, ND: Non-dominant side, Max: Maximum, N: Newton, SD: Standard deviation, F: ANOVA test statistic, M: Male, F: Female, $p<0.05$

As a result of the comparison of the eccentric hamstring strength of the volleyball players according to the positions, it was determined that there was no statistically significant difference between the maximum and mean eccentric hamstring muscle strengths and muscle strength differences of both female (F=0.403-5.331;p=0.255-0.982) and male (F=4.167-6.985; p=0.137-0.384) athletes. In addition, there was no significant difference between male and female athletes in terms of mean and maximum eccentric hamstring muscle strength and muscle strength differences according to their positions (F=0.001-3.823; p=0.055-0.972) (Table 2).

DISCUSSION AND CONCLUSION

In this study, which aimed to compare the eccentric hamstring muscle strength levels of elite volleyball players according to their playing positions, it was found that there was no significant difference in terms of maximum and mean eccentric hamstring muscle strength of both male and female athletes according to their playing positions. To the best of our knowledge, no previous studies have examined the isolated eccentric hamstring strength of volleyball players based on their playing positions, although a few studies have evaluated hamstring muscle strength in relation to playing positions. Aka et al. (31) compared concentric quadriceps and hamstring isokinetic muscle strengths in volleyball players according to positions. As a result of the study, it was determined that there was no significant difference between the concentric quadriceps and hamstring muscle strengths of spikers, passers, and middle players at angular velocities of 60°s-1 and 180°s-1.

In contrast to this data, Küçükbaycan et al. (32) reported that there was no difference between the leg muscle strengths of spikers and middle players before the preparation period, but after the preparation period, the leg strengths of middle players were significantly higher than those of spikers in their study in which they compared the leg muscle strengths of female volleyball players before and after the preparation period according to their positions. Margues et al. (33) found that there were serious anthropometric and strength differences between the playing positions of male volleyball players and squat performance of passers was lower than other volleyball players. When the studies conducted in different sports branches were examined, Yılmaz et al. (34) stated that defenders had higher knee flexion and extension muscle strengths at an angular velocity of 60°sec-1 than forwards and midfielders in their study in which they compared isokinetic knee strengths according to positions in football players. Other studies comparing isokinetic knee strength in football players according to positions showed that defenders had higher strength ratios than forwards and midfielders (35,36). From this point of view, it was thought that the fact that defenders showed higher ratios at lower angular velocities compared to midfielders and forwards was the result of the fact that defenders had to move faster in the game to prevent opponent attacks and had to react instantaneously in defense. Tourny-Chollet et al. (36) reported that forwards had higher concentric hamstring muscle strength than center players. These differences were attributed to the higher forces produced by strikers at low and medium speeds during knee flexion. When the results of all these studies are analyzed, it is seen that there is no common opinion on strength comparisons between playing positions in existing studies, including our study. In addition, in these studies, comparisons were made according to concentric quadriceps and hamstring strengths. In our study, maximum and mean eccentric hamstring strength were evaluated. This focus on eccentric strength is a strength of our study and will serve as a reference for future research in this area. Because in the current literature, the strongest evidence among the risk factors of HFM is expressed as eccentric hamstring muscle strength weakness (3). Therefore, evaluating eccentric hamstring muscle strength is crucial in identifying injury risks in athletes and tailoring individual training programs according to their positions.

The practical implications of these findings are significant for training and injury prevention strategies. Coaches and sports scientists should consider incorporating regular assessments of eccentric hamstring strength into their training programs, regardless of the player's position. Such assessments can help in identifying potential weaknesses or imbalances that may predispose athletes to injury. Moreover, developing targeted strength and conditioning programs that address eccentric strength can be beneficial in enhancing overall performance and reducing injury risk. Given that no significant differences were found across positions, a uniform approach in training for eccentric hamstring strength may be effective.

This study presents several limitations that need to be acknowledged. Firstly, the sample size, while sufficient for initial exploration, may not capture the full variability within elite volleyball players' eccentric hamstring strength across different positions. Thus, results should be interpreted with caution when generalizing to broader populations. Secondly, the study exclusively focused on elite athletes from the Turkish Volleyball 1st League; therefore, findings may not directly apply to athletes from different competitive levels or leagues, potentially limiting the external validity of the study. Another limitation is the study's reliance on a single method (Nordic Hamstring exercise using the IVMES H-Bord device) for assessing eccentric hamstring muscle strength. While this method is widely accepted and provides valuable information, it does not encompass all aspects of hamstring function relevant to volleyball performance. Additionally, the study did not account for variables such as previous injury history or individual differences in training outside the team's program, which could influence eccentric hamstring strength. Moreover, the cross-sectional design limits the ability to infer causality or changes over time, hindering the understanding of how eccentric hamstring strength might evolve across a season or in response to specific training interventions. Lastly, the classification of players into positions, while necessary for the study's objectives, does not account for the fluidity of player roles and the multifaceted nature of volleyball, where players may perform tasks outside their primary positions.

Future research should consider longitudinal designs, larger and more diverse samples, and comprehensive assessments of hamstring function to build on the findings of this study. Exploring other dimensions of hamstring strength, such as concentric and isometric strengths, and their impact on performance and injury prevention in volleyball could provide a more holistic understanding of the muscle group’s role. Additionally, integrating various assessment methods and considering the influence of training history and injury background could offer deeper insights into the development and maintenance of hamstring strength in volleyball players.

CONCLUSIONS

As a result of our study, we demonstrated that the grip strength of the dominant hand was higher with the bilateral grip compared to the unilateral grip, providing compelling evidence for the PNF irradiation principle. This finding is novel as it underscores the effectiveness of bilateral grip strength training, which has not been extensively explored in the current literature. Additionally, this information highlights the bilateral approach as a promising treatment option in training programs aimed at strengthening muscles and enhancing motor skills.

Given the novelty of our findings, further research is warranted to build on these results. Future studies should consider exploring the impact of bilateral grip strength training across different populations, including athletes from various sports, elderly individuals, and those undergoing rehabilitation. Additionally, investigating the long-term effects of bilateral versus unilateral training on muscle strength and motor skill development could provide deeper insights. Researchers should also examine other muscle groups and motor activities to determine if the benefits observed with bilateral grip strength training extend to other areas. Lastly, integrating different assessment methods and considering factors such as training history, injury background, and specific athletic demands could help in understanding the broader applicability and effectiveness of the bilateral approach.

Conflicts of interest and Funding

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