



## The Relationship of Hand Grip Strength with Bone Mineral Density and Vitamin D in Postmenopausal Women

Postmenopozal Kadınlarda El Kavrama Gücünün Kemik Mineral Yoğunluğu ve D Vitamini ile İlişkisi

Münevver Serdaroğlu Beyazal, Gül Devrimsel, Ayşegül Küçükali Türkyılmaz, Murat Yıldırım

Recep Tayyip Erdoğan University Faculty of Medicine, Department of Physical Medicine and Rehabilitation, Rize, Turkey

### Summary

**Objective:** The aim of the present study was to evaluate the relationship of hand grip strength (HGS) with bone mineral density (BMD) and vitamin D levels in postmenopausal women.

**Materials and Methods:** One hundred thirty one postmenopausal women were included in this study. HGS was measured by Jamar hand dynamometer. BMD was measured by dual energy X-ray absorptiometry at lumbar spine and femoral neck sites. Serum 25-hydroxyvitamin D (25OHD) levels were measured.

**Results:** The mean age of patients was 61.2±9.2 years. The mean HGS was 22.9 kg and 32 patients (24.4%) had low HGS. Thirty seven patients (28.2%) were osteoporotic and 62 (47.3%) were osteopenic. The mean 25OHD level was 17 ng/mL and 101 (77.1%) patients having vitamin D insufficiency. There was a significant difference in HGS values among groups with osteoporosis, osteopenia, and normal BMD ( $p=0.016$ ). HGS values demonstrated a positive correlation with T-scores and BMD values at lumbar spine and femoral neck sites ( $p<0.001$ ,  $r=0.340$ ;  $p<0.001$ ,  $r=0.300$ ;  $p<0.001$ ,  $r=0.320$ ;  $p=0.001$ ,  $r=0.298$ , respectively) and negative correlation with age and duration of menopause ( $p<0.001$ ,  $r=-0.344$ ;  $p<0.001$ ,  $r=-0.318$ ; respectively). However, no significant association was observed between 25OHD levels and HGS ( $p=0.860$ ,  $r=0.016$ ).

**Conclusion:** Postmenopausal women with osteoporosis had lower HGS than postmenopausal women with normal BMD, and HGS was significantly correlated with BMD, but not with vitamin D in this population. The patients should be encouraged to increase muscle strength for the risk management of osteoporosis in postmenopausal women.

**Keywords:** Muscle strength, hand grip strength, bone mineral density, vitamin D

### Öz

**Amaç:** Bu çalışmanın amacı postmenopozal kadınlarda el kavrama gücünün (EKG) kemik mineral yoğunluğu (KMY) ve D vitamin seviyeleri ile ilişkisini değerlendirmektir.

**Gereç ve Yöntem:** Çalışmaya 131 postmenopozal kadın alındı. EKG Jamar el dinamometresi ile ölçüldü. KMY dual enerji X-ray absorpsiyometri ile lomber omurga ve femur boyun bölgelerinden ölçüldü. Serum 25-hidroksivitamin D (25OHD) seviyeleri tespit edildi.

**Bulgular:** Hastaların yaş ortalaması 61,2±9,2 yıl idi. Ortalama EKG 22,9 kg idi ve 32 hasta (%24,4) düşük EKG'ye sahipti. Otuz yedi hasta (%28,2) osteoporotik, 62 hasta (%47,3) osteopenikti. Ortalama 25OHD düzeyi 17 ng/mL idi ve 101 hasta (%77,1) D vitamini yetersizliğine sahipti. Osteoporoz, osteopeni ve normal KMY'ye sahip gruplar arasında EKG bakımından anlamlı farklılık vardı ( $p=0,016$ ). EKG değerleri lomber omurga ve femur boyun kısımlarındaki T skorları ve KMY değerleri ile pozitif korelasyon ( $p<0,001$ ,  $r=0,340$ ;  $p<0,001$ ,  $r=0,300$ ;  $p<0,001$ ,  $r=0,320$ ;  $p=0,001$ ,  $r=0,298$  sırasıyla), yaş ve menopoz süresi ile negatif korelasyon ( $p<0,001$ ,  $r=-0,344$ ;  $p<0,001$ ,  $r=-0,318$  sırasıyla) gösterdi. Ancak, EKG ve 25OHD seviyeleri arasında herhangi bir ilişki bulunmadı ( $p=0,860$ ;  $r=0,016$ ).

**Sonuç:** Osteoporoz tanısı olan postmenopozal kadınlar, normal KMY'ye sahip postmenopozal kadınlardan daha düşük EKG'ye sahiptir ve EKG bu toplumda KMY ile ilişkili iken, D vitamini ile ilişkili değildir. Postmenopozal kadınlardaki osteoporoz risk yönetiminde hastalar kas gücünün artırılması yönünde teşvik edilmelidirler.

**Anahtar kelimeler:** Kas gücü, el kavrama gücü, kemik mineral yoğunluğu, D vitamini

## Introduction

The aging process is accompanied by the progressive decline in bone mineral density (BMD), muscle mass, and muscle strength. The reduction of bone mass is a key feature of osteoporosis (OP), which is defined in an individual with a BMD T-score at least 2.5 standard deviations (SD) below the normal T-score in young adults (1). Sarcopenia is a syndrome characterised by progressive and generalised loss of skeletal muscle mass and strength with a risk of adverse outcomes (2). It represents an impaired state of health with a high personal toll-mobility disorders, increased risk of falls and fractures, impaired ability to perform activities of daily living, disabilities, and loss of independence and increased risk of death.

The association between bone and muscle has been supposed to be mechanical. The skeleton adapts to stress and mechanical loads with muscle exerting powerful loading forces on the bone (3). Vitamin D receptor expression in bone and muscle reduces in elderly. So, it is probable that the decline in vitamin D level play an integral role in the functional association between OP and sarcopenia. Vitamin D exhibits its effects via genomic and non-genomic pathways (4). These pathways can affect muscle function. In addition, vitamin D could also affect neuromuscular action. Long duration vitamin D deficiency in older age results in decreases in both BMD and type 2 muscle fibers with the consequence of skeletal fragility in combination with muscle power, which could cause increased falls risk.

Low hand grip strength (HGS) is a clinical marker of poor mobility and a better predictor of clinical outcomes than low muscle mass (2). It was also reported that good muscle strength and its maintenance are associated with higher BMD and lower bone loss rate (5). In *Os des Femmes de Lyon* study, it was demonstrated that grip strength is one of the independent predictors of all OP related fractures in healthy postmenopausal women (6). In the present study, we evaluated HGS in conjunction with vitamin D status in postmenopausal women admitted to our outpatient clinic and investigated whether HGS is associated with vitamin D level and BMD in this population.

## Materials and Methods

This cross-sectional study was conducted between May 2014 and September 2014. The study protocol was approved by the local ethics committee of our institution. The study was performed in accordance with the principles stated in Declaration of Helsinki and written informed consent was obtained from all participants prior to the study. One hundred thirty-one consecutive postmenopausal women were enrolled. Subjects were excluded if they showed other known causes of OP, such as endocrine and rheumatic diseases, or had history of therapy with corticosteroids or anti-osteoporotic medication, cervical radiculopathy, carpal tunnel syndrome, hand or elbow deformity, or neuromuscular disease. Sociodemographic characteristics including age, gender, weight, height, duration of menopause, reproductive history were recorded. Body mass index (BMI) was

calculated by dividing weight in kilograms by height in meters squared. Jamar hand dynamometer (kg) was used for the evaluation of maximum HGS (7). HGS was measured from the dominant hand while sitting, with the forearm flexed from the elbow at 90° angle. A total of three attempts were taken, with approximately 30s of resting time between the tests. A mean value was recorded. Low muscle strength was defined as HGS at  $\leq 17$  kg if BMI is  $\leq 23$ ,  $\leq 17.3$  kg if BMI is 23.1-26,  $\leq 18$  kg if BMI is 26.1-29, and  $\leq 21$  if BMI is  $>29$  (2).

Using dual energy X-ray absorptiometry (DXA, Lunar Prodigy; Madison, WI, USA), BMD measurements were obtained both from the lumbar spine (L1-4) and left femoral neck sites. BMD values were expressed in  $\text{g}/\text{cm}^2$ . World Health Organisation classification range was used to categorize subjects as normal ( $T > -1$ ), osteopenic ( $-2.5 < T \leq -1$ ), or osteoporotic ( $T \leq -2.5$ ) (8).

Serum samples of all participants were collected for biochemical analysis. Serum concentrations of calcium (Ca), phosphorus (P), and alkaline phosphatase (ALP) were measured by standard autoanalyzer technique using Architect C1600® (Abbott). Serum 25-hydroxyvitamin D (25OHD) was assessed by chemiluminescent microparticle immunoassay (Architect system, Abbott Diagnostic, Germany). Based on serum 25OHD concentration, vitamin D status was categorized as insufficient (less than 20 ng/mL) and sufficient (more than 20 ng/mL) (9). All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 13.0, for Windows (SPSS, Chicago, IL, USA). Continuous variables were presented as the mean  $\pm$  SD. The normality of the distribution for all variables was assessed by the Kolmogorov-Smirnov test. Intergroup comparisons were performed using the Student's t-test for normally distributed variables and the Mann-Whitney U test for non-parametric variables. The subgroups analyses of patients with OP, osteopenia, and normal BMD were performed using one way analysis of variance test. Tamhane or Tukey post-hoc analysis was performed to detect differences between subgroups according to results of homogenisate. To assess the correlations between variables, Spearman's rank or Pearson's correlation analyses were used according to data distribution. In addition, partial correlation analysis was performed to eliminate confounding factor such as age in the evaluation of association between HGS and other parameters. A value of  $p < 0.05$  was statistically significant.

## Results

The demographic and clinical characteristics of subjects are presented in Table 1. The mean age was  $61.2 \pm 9.2$  (range 45-81) years. The prevalences of OP and osteopenia were 28.2% and 47.3%, respectively. The mean 25OHD level was  $17.02 \pm 6.9$  ng/mL (range 5.9-45.1) with 101 (77.1%) having vitamin D insufficiency. The mean HGS was  $22.9 \pm 6.3$  kg (range 8-46) and 24.4% of subjects had low HGS.

Comparisons of demographic and clinical parameters among three subgroups (OP, osteopenia, normal) are shown in Table 2.

Although subjects with OP had the lowest 25OHD level, there was no statistically significant difference in 25OHD levels among subgroups ( $p>0.05$ ). The mean Ca, P, ALP, and parathyroid hormone (PTH) concentrations also did not demonstrate significant difference among subgroups (all  $p>0.05$ ). There was a significant difference in the mean age, height, weight, duration of menopause, and HGS among subgroups ( $p=0.001$ ,  $p=0.002$ ,  $p=0.005$ ,  $p=0.001$ , and  $p=0.016$ ; respectively). While subjects with normal BMD had significantly younger age compared to subjects with OP and osteopenia (Tamhane post-hoc analysis;  $p=0.000$ ,  $p=0.002$ , respectively), there was no significant difference between subjects with OP and osteopenia. Subjects with normal BMD also had higher weight and lower duration of menopause compared to subjects with OP and osteopenia (Tukey post-hoc analysis;  $p=0.004$ ,  $p=0.042$ ;  $p=0.001$ ,  $p=0.009$ , respectively), whereas no significant difference was observed

between subjects with OP and osteopenia for these parameters. While subjects with OP had lower height compared to subjects with normal BMD (Tamhane post-hoc analysis;  $p=0.006$ ), there was no significant difference between subjects with osteopenia and OP and with osteopenia and normal BMD. Whereas there was no significant difference in HGS between subjects with OP and osteopenia and with osteopenia and normal BMD, subjects with OP had decreased HGS compared to subjects with normal BMD (Tukey post-hoc analysis,  $p=0.013$ ).

Subjects with vitamin D insufficiency showed statistically significant lower T-scores and BMD values at femoral neck site and higher PTH levels compared to subjects with vitamin D sufficiency ( $-0.946\pm 1.09$  vs  $-0.323\pm 1.37$ ,  $p=0.011$ ;  $0.758\pm 0.138$  vs  $0.853\pm 0.190$  g/cm<sup>2</sup>;  $p=0.003$ ;  $66.8\pm 22.7$  vs  $53.2\pm 16.9$  pg/mL,  $p=0.003$ , respectively). There was no significant difference in T-scores and BMD values at lumbar spine, HGS, and other studied parameters between groups (all  $p>0.05$ , data not shown).

HGS values demonstrated a positive correlation with lumbar spine and femoral neck T-scores and BMD values ( $p<0.001$ ,  $r=0.340$ ;  $p<0.001$ ,  $r=0.300$ ;  $p<0.001$ ,  $r=0.320$ ;  $p=0.001$ ,  $r=0.298$ , respectively). However, no significant correlation was observed between 25OHD levels and HGS ( $p=0.860$ ,  $r=0.016$ ) (Table 3). In addition, HGS was also significantly correlated with age, height, weight, BMI, and duration of menopause ( $p<0.001$ ,  $r=-0.344$ ;  $p=0.002$ ,  $r=0.268$ ;  $p=0.001$ ,  $r=0.280$ ;  $p=0.039$ ,  $r=0.181$ ;  $p<0.001$ ,  $r=-0.318$ ; respectively). In second step, we used partial correlation analysis to adjust age in assessment of the association between HGS and BMD. The association of 25OHD levels with T-scores and BMD values at lumbar spine and femoral neck also persisted in this analysis ( $p=0.001$ ,  $r=0.276$ ;  $p=0.041$ ,  $r=0.180$ ;  $p=0.002$ ,  $r=0.271$ ;  $p=0.043$ ,  $r=0.178$ ; respectively).

## Discussion

OP and sarcopenia are common diseases that predominantly affect older individuals (10). They are both associated with significant morbidity and can therefore lead to considerable health and social costs. Sarcopenia might also decrease bone strength by reducing mechanical loading to the skeleton. Reduction of mechanical stimulation could result from decreased maximal force that weaker muscles produce and/or less time that the skeleton is loaded due to relative immobility, and thus bone formation is reduced (11).

Muscle strength plays a widely recognized key role in overall functional status, particularly in the elderly. Skeletal muscle impairment is closely associated with a decline of daily activities, increased risk of institutionalization, cognitive decline and accelerated mortality (12). In this study, we performed HGS measurement to evaluate muscle strength. It has been found that isometric HGS is strongly related with lower extremity muscle power, knee extension torque and calf cross sectional muscle area (2). In practice, a linear relationship between

**Table 1. Demographic and clinical characteristics of the subjects**

|  | Subjects (n=131) |
|--|------------------|
| Age (years)  | 61.3±9.2         |
| Height (m)   | 1.58±0.1         |
| Weight (kg)  | 75.2±11.1        |
| BMI (kg/m <sup>2</sup> )   | 30.23±4.4        |
| Age at menopause (years)   | 46.6±4.7         |
| Age at menarche (years)  | 13.4±1.01        |
| Duration of menopause (years)  | 14.1±9.4         |
| Pregnancy (n)  | 3.9±1.7          |
| HGS (kg)   | 22.9±6.3         |
| Pinch (kg)   | 5.3±1.3          |
| 25OHD (ng/mL)  | 17.02±6.9        |
| Ca (mg/dL)   | 9.7±0.5          |
| P (mg/dL)  | 3.7±0.7          |
| ALP (U/L)  | 80.3±22.3        |
| PTH (pg/mL)  | 63.7±22.2        |
| Low HGS n (%)  | 32 (24.4)        |
| 25OHD insufficiency n (%)  | 101 (77.1)       |
| 25OHD sufficiency (%)  | 30 (22.9)        |
| BMD (g/cm <sup>2</sup> )   |                  |
| Lumbar spine (L1-4)  | 0.882±0.154      |
| Femoral neck   | 0.780±0.156      |
| T-scores   |                  |
| Lumbar spine   | -1.56±1.30       |
| Femoral neck   | -0.80±1.19       |
| Osteoporosis n (%)   | 37 (28.2)        |
| Osteopenia n (%)   | 62 (47.3)        |
| Values are presented as mean ± standard deviation, BMI: Body mass index, HGS: Hand grip strength, 25OHD: 25-hydroxyvitamin D, Ca: Calcium, P: Phosphorus, ALP: Alkaline phosphatase, PTH: Parathyroid hormone, BMD: Bone mineral density |                  |

baseline HGS and incident disability for activities of daily living also has been demonstrated (13). In this study, the mean HGS value was 22.9 kg and patients with OP had decreased HGS compared to patients with normal BMD. HGS also showed a statistically significant negative association with the duration of menopause and age and positive association with femoral neck and lumbar spine BMD. In a study by Şahin et al. (14), although the mean age was younger than those in our study, the mean HGS value (22.7 kg) was similar to ours. In accordance with our results, they also demonstrated a significant, but weak correlation of HGS with age, duration of menopause, and femoral neck BMD. In a study by Rikkonen et al. (15), patients with OP had significantly decreased grip strength and knee extension strength compared to subjects with osteopenia and normal BMD. The authors concluded that muscle strength, especially grip strength, serve as an independent and useful tool for postmenopausal OP risk assessment. Marin et al. (16) evaluated 117 physically active postmenopausal women (67.8±7.0 years) who performed neuromotor physical tests (strength, balance, and mobility). In that study, among the functional variables studied, the HGS was the one that best correlated with BMD in all analyzed sites and remained important in the multiple regression analyses, corrected for chronological and menopausal age. Kaya et al. (17) evaluated the relationship between grip strength and hand BMD in healthy adults, and found moderate correlation between these two parameters in men, but not in premenopausal women. In a another study, they also showed a close correlation of grip strength with BMD in postmenopausal women, but not in premenopausal women (18). On the other hand, another study by Bayramoğlu et al. (19) showed no significant correlation between lumbar spine BMD and trunk muscle strength or distal radius BMD and grip strength in sedentary postmenopausal

women. However, a weak but statistically significant correlation between femoral BMD and hip abductor muscle strength was observed in that particular study. Their study also showed that the women with osteoporotic distal radii had lower HGS than the women who were normal or osteopenic in this region. In a 10-year prospective follow-up study evaluated the association between change in age-grouped grip strength quartile and postmenopausal bone loss in a population based random sample of 622 Finnish women, it was demonstrated that improved age grouped grip strength status is significantly associated with lower postmenopausal bone loss (20).

In addition, the usefulness of grip strength measurement in conjunction with central DXA in prediction of perimenopausal fractures was evaluated in a 15-year population-based follow-up study (5). Accordingly, grip strength proved to be highly predictive of fracture-free survival rate in perimenopausal women with normal BMD and was the only predictive variable among these women for fractures in addition to T-score. Another population-based study has also demonstrated that low grip strength was associated with reduced BMD at both the lumbar spine and femoral neck in women and an increased risk of incident vertebral fracture among women (21).

Various clinical studies underline the potential role of vitamin D on skeletal muscle structure and function, while vitamin deficiency appears to be associated with changes in muscle morphology (22). As an example, patients with vitamin D deficiency are suffering from osteomalacic myopathy. Vitamin D deficiency is common in the elderly, especially in institutionalized patients, and it is associated with sarcopenia and disability. In this study, vitamin D status was also evaluated and found that the majority of our subjects had vitamin D insufficiency. However, there was no correlation between vitamin D levels and HGS in this population. The number of patients with OP and

**Table 2. The comparison of subjects according to bone mineral density status**

|                               | Osteoporosis<br>(n=37) | Osteopenia<br>(n=62) | Normal<br>(n=32) | p     |
|-------------------------------|------------------------|----------------------|------------------|-------|
| Mean age (years)              | 64.2±9.1               | 62.1±9.5             | 56.3±6.4         | 0.001 |
| Height (m)                    | 1.56±0.01              | 1.57±0.03            | 1.59±0.04        | 0.002 |
| Weight (kg)                   | 71.8±11.4              | 74.5±10.4            | 80.3±10.6        | 0.005 |
| BMI (kg/m <sup>2</sup> )      | 29.3±4.8               | 30.1±4.1             | 31.5±4.4         | 0.105 |
| Duration of menopause (years) | 17.2±9.8               | 14.9±9.4             | 9.03±7.1         | 0.001 |
| Age of menopause (years)      | 47.08±4.6              | 46.9±4.8             | 46.9±4.9         | 0.982 |
| Number of pregnancies         | 4.08±1.9               | 4.1±1.9              | 3.5±1.4          | 0.246 |
| HGS (kg)                      | 21.2±5.7               | 22.7±6.4             | 25.5±6.3         | 0.016 |
| 25OHD level(ng/mL)            | 15.6±4.5               | 18.1±8.01            | 16.6±6.74        | 0.191 |
| Ca (mg/dL)                    | 9.6±0.5                | 9.8±0.4              | 9.6±0.7          | 0.746 |
| P (mg/dL)                     | 3.8±1.0                | 3.7±0.5              | 3.7±0.6          | 0.850 |
| ALP (U/L)                     | 86.3±22.9              | 79.8±22.9            | 80.4±22.3        | 0.094 |
| PTH (pg/mL)                   | 69.4±28.1              | 60.9±18.8            | 62.6±20.0        | 0.171 |

Values are presented as mean ± standard deviation, BMI: Body mass index, HGS: Hand grip strength, 25OHD: 25-hydroxyvitamin D, Ca: Calcium, P: Phosphorus, ALP: Alkaline phosphatase, PTH: Parathyroid hormone

**Table 3. The correlation of hand grip strength with studied parameters**

|                                       | Hand grip strength (kg) |       |
|---------------------------------------|-------------------------|-------|
|                                       | r                       | p     |
| Age (years)                           | -0.344                  | 0.000 |
| Height (m)                            | 0.268                   | 0.002 |
| Weight (kg)                           | 0.280                   | 0.001 |
| BMI (kg/m <sup>2</sup> )              | 0.181                   | 0.039 |
| Duration of menopause (years)         | -0.318                  | 0.000 |
| 25OHD level (ng/mL)                   | -0.016                  | 0.860 |
| Lumbar spine T-score                  | 0.340                   | 0.000 |
| Femoral neck T-score                  | 0.300                   | 0.000 |
| Lumbar spine BMD (g/cm <sup>2</sup> ) | 0.320                   | 0.000 |
| Femoral neck BMD (g/cm <sup>2</sup> ) | 0.298                   | 0.001 |

BMD: Bone mineral density, BMI: Body mass index, 25OHD: 5-hydroxyvitamin D

severe vitamin D insufficiency was relatively small in this study. Also, because of the cross-sectional study design, we could not evaluate the duration of vitamin D insufficiency which has been shown to be more important than isolated vitamin D insufficiency. A case control study by Dhanwal et al. (23) demonstrated that the majority of hip fracture patients had lower 25OHD levels and HGS compared to controls and that there was a significant positive correlation between 25OHD levels and HGS in hip fracture patients (23). A 3-year population-based prospective follow-up study demonstrated that lower 25OHD levels and higher PTH levels increase the risk of sarcopenia in older men and women (24). In that study, subjects with lower 25OHD levels were more likely to experience loss of grip strength. On the other hand, another community-based prospective cohort study did not support the hypothesis that vitamin D deficiency is associated with loss in muscular strength and decline in mobility and upper extremity functioning over time in older women who were moderately to severely disabled at baseline (25). In addition, cross-sectional analysis of baseline data revealed that none of the performance measures (hip flexor, knee extensor, and grip strength; walking speed; and time for five repeated chair stands) was significantly associated with 25OHD or PTH levels after adjustment for potential confounders in that cohort study. Similar results were also demonstrated in other studies (26-28). Numerous studies have investigated the effect of vitamin D supplementation on muscle strength and physical performance in elderly female population. A systematic review and meta-analysis conducted in 2011 concluded that vitamin D supplementation does not have a significant effect on muscle strength in adults with baseline 25OHD level >25 nmol/L (29). A recently published systematic review and meta-analysis of randomized controlled trials demonstrated that vitamin D supplementation has a small but significant positive effect on global impact on muscle strength, but no effect on muscle mass and muscle power (30). Regarding the individual type

of strength, results revealed no significant effect of vitamin D supplementation on grip strength, but a significant positive effect on lower limb muscle strength in that meta-analysis. In conclusion, this study demonstrated that postmenopausal women with OP had lower HGS compared to subjects with normal BMD and detected significant correlation of HGS with BMD at both lumbar spine and femoral neck sites, but not with 25OHD level in postmenopausal women. Patients should be encouraged to increase muscle strength for the risk management of OP in postmenopausal women. However, further follow-up studies involving large samples are required to clarify the association between HGS and 25OHD status.

### Ethics

Ethics Committee Approval: Recep Tayyip Erdoğan University Ethics Committee. Informed Consent: It was taken.

Peer-review: Internal peer-reviewed.

### Authorship Contributions

Concept: Münevver Serdaroğlu Beyazal, Design: Münevver Serdaroğlu Beyazal, Data Collection or Processing: Münevver Serdaroğlu Beyazal, Gül Devrimsel, Ayşegül Küçükali Türkyılmaz, Murat Yıldırım, Analysis or Interpretation: Münevver Serdaroğlu Beyazal, Gül Devrimsel, Ayşegül Küçükali Türkyılmaz, Murat Yıldırım, Literature Search: Münevver Serdaroğlu Beyazal, Writing: Münevver Serdaroğlu Beyazal.

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